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HIGHLIGHTS

- A significant amount of time and effort was expended to convert the model code running on the Cray computers over to the IBM SP. Any differences in the output from the two different runs needed to be accounted for and explained. The suite of benchmark codes consisting of 9 suites of runs for the Meso Eta Model and the global spectral model were run and achieved ~5x speed up over the Cray C-90.

- The hourly RUC2 and the 4-per-day Eta became operational on the IBM SP in Bowie, MD on Nov 18, 1999.

- An easily reconfigured, multi-platform version of the Eta Model was made available in May 1999. This system allows the user to run the Eta at their own site on a UNIX/LINUX workstation and the ability to download real-time data from NCEP models.

- Work continues on the nonhydrostatic Eta. It appears to be computationally robust at all resolutions and efficient in NWP applications. Forecasts of traditional meteorological parameters between the hydrostatic and nonhydrostatic versions are almost indistinguishable by eye.

- In conjunction with NCAR, FSL, and the University of Oklahoma, development has begun for the new Weather Research and Forecasting (WRF) Model. The WRF will combine the expertise of operational and research modelers in collaborative development of an improved mesoscale weather forecast modeling and data assimilation system. The WRF will be a nonhydrostatic model and be designed for 1-10 km horizontal resolution with advanced data assimilation and physics. It will be accurate and efficient across a broad range of scales and will be well suited for both research and operations.

- A single column model version of the NCEP MRF model has been developed. It will enable programmers to evaluate and debug changes in the physics packages. It will also be useful in diagnosing model behavior.

- In mid March 1999, the NOAA-15 HIRS/3 and AMSU-A radiances were added to the global models. It assimilates the data and decomposes the bias of all radiances into three components.

- A targeted observation study underway is showing some

promising results. An area where significant weather is expected to develop in the future is identified. Then using the Ensemble Transform method, an area to have extra dropsondes taken is identified. The results show a positive impact on the quality of surface pressure, tropospheric winds and precipitation forecasts in the target area.

- A new third generation global ocean surface wave forecast model has been developed, evaluated, and approved for operational implementation at NCEP. The model uses a 1.0/1,25 latitude/longitude resolution. This model referred to as the NOAA WaveWatchIII (NWW3) has replaced the current operational WAM_Cycle 4 wave model on the IBM machine.

- Two new regional wave forecast models, one for the northwest Atlantic region and another for the Gulf of Alaska and Bering Sea region have been developed and evaluated. Both models are based on the physics and numerics of the NWW3 model. The grid resolution in these regional models is 0.25 degrees in latitude and longitude. These will also replace the current operational regional models on the IBM machine.

- NSCAT data assimilation experiments with the global NWP model showed little impact in the Northern Hemisphere and slightly more impact on the Southern Hemisphere. An evaluation of the NSCAT retrievals appears to show possible contamination by rain.

- A Coastal Marine Demonstration Project has been conducted off the East Coast of US surrounding the Chesapeake Bay area during June-July, 1999. The purpose of the demonstration is to provide guidance forecast products of several marine fields such as the ocean surface winds, fog and visibility, etc. as well as ocean parameters such as surface currents, SSTs, water levels, etc. to a set selected users from commercial and recreational communities and evaluate their usefulness. Feed back from the selected users has been collected and is currently being evaluated.

- Sea ice drift forecasts have been extended to 16 days to provide longer range guidance to the Alaskan region.

- Efforts to develop the MOS-2000 system and the next generation of centralized MOS guidance were well underway. (See 2.1.1)

- Version 2.0 of the System for Convection Analysis and Nowcasting (SCAN), which includes the functionality of the

National Severe Storms Laboratory's Warning Decision Support System, was prepared for AWIPS implementation. (See 2.1.2)

- The LAMP system analysis was modified to handle variable grid spacing. The LAMP QPF system was prepared for AWIPS implementation. (See 2.1.2)

- An extratropical storm surge model to forecast water heights along the northwest coast of the U.S. was developed. (See 2.1.3)

- Development and testing of interactive forecast preparation and product generation techniques for public and various specialized weather forecasts continued with a dual emphasis on completing techniques to generate products in the current product suite as well as preparing new grid-based forecast products. (See 2.1.4)

- The Operational Cray C-90 caught on fire on Sep 27, 1999. The fire put the C-90 permanently out of service. This, combined with having to move the new IBM SP to the Bowie, MD due to unfavorable environmental conditions in the Suitland facility, resulted in going into backup mode. Due to running the Eta at 80 km resolution, there was a degradation of the Eta model from 28 Sep to 18 Nov. FSL had to send the 40 km MAPS to back up the RUC2. The AVN was only run twice a day instead of four times a day. There were no ensembles produced during this time period and the MRF was run out to only 10 days instead of 14.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACARS	ARINC Automated Communications and Addressing Reporting System
ARL	Air Resources Laboratory
AFOS	Automated of Field Operations and Services
ARM	Atmospheric Radiation Measurements
ASOS	Automated Surface Observing System
ADD	Atmospheric Turbulence and Diffusion Division
AVN	Aviation [Run]
AWC	Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
BUFR	Binary Universal Format for data Representation
CADB	Climate Assessment Data Base
CAFTI	Committee on Analysis and Forecast Techniques Implementation
CAMS	Climate Anomaly Monitoring System
CAPE	Convective Available Potential Energy
CAPS	Center for the Analysis and Prediction of Storms
CDAS	Climate Data Assimilation System
CINH	Convective Inhibition
CMAP	CPC Merged Analysis of Precipitation
CMDP	Coastal Marine Demonstration Project
COARE	Coupled Ocean Atmosphere Response Experiment
COFS	Coastal Ocean Forecast System
CONDUIT	Cooperative Opportunity for NCEP Data Using IDD Technology
CONUS	Continental United States
CPC	Climate Prediction Center
CQCBUFR	Quality Control Module for Radiosonde Data.
CQCVAD	Quality Control Module for VAD Wind Profiles from WSR-88D Radars
DMSP	Defense Meteorological Satellite Program
DOE	Department of Energy
DSP	Deficit Saturation Pressure
ECMWF	European Center for Medium Range Weather Forecasts
EDAS	Eta-based Data Assimilation System
EMC	Environmental Modeling Center
ENSO	El Nino Southern Oscillation
EOF	Empirical Orthogonal Function
ERS-2	European Remote Sensing Satellite-2
ERL	Environmental Research Laboratory
ETS	Equitable Threat Score
FNL	Final [Run]
FSL	Forecast Systems Laboratory
FVS	Forecast Verification System
GCM	General Circulation Model
GCIP	GEWEX Continental-scale International Project

GDAS	Global Data Assimilation System
GEMPAK	General Meteorological Package
GEWEX	Global Energy and Water-cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GHM	GFDL Hurricane Model
GIS	Geographical Information System
GOES	Geostationary Operational Environmental Satellite
GPCP	Global Precipitation Climatology Project
GRIB	Gridded Binary
GSFC	Goddard Space Flight Center
GTS	Global Telecommunications System
HCN	Hurricane [Run]
HIRS	High Resolution Infrared Spectrometer
HRD	Hurricane Research Division
HYBNNCEP	Takes Eta files and makes boundary conditions for the RUC
ICWF	Interactive Computer Worded Forecast
IFPS	Interactive Forecast Preparation System
IR	Infrared
LAMP	Local AWIPS MOS Program
LDAS	Land Data Assimilation System
LSM	Land Surface Model
LW	Long Wave
MAPS	Mesoscale Analysis and Prediction System
Max	Maximum
MERGE	Merge of Eta RUC and Global-AVN by EMC
METAR	Aviation Routine Weather Report
Min	Minimum
MOLTS	Model Output Level Time Series
MOS	Model Output Statistics
MPI	Message Passing Interface
MPP	Multi-Processor Parallel
MRF	Medium-Range Forecast
MSO	Mesoscale [Run]
MSU	Microwave Sounding Unit
NAOS	North American Observing System
NASA	National Aeronautics and Space Administration
N-AWIPS	National Center AWIPS
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NESDIS	National Environmental Satellite, Data, and Information Service
NGM	Nested Grid Model
NH	Northern Hemisphere
NIDS	NEXRAD Information Dissemination Service
NOAA	National Oceanic and Atmospheric Administration

NOAH LSM	NCEP, Oregon State University, Air Force and Office Of Hydrology Land-Surface Model
NPA	National Precipitation Analysis
NSSL	National Severe Storms Laboratory
NWP	Numerical Weather Prediction
NWS	National Weather Service
NWW3	NOAA WaveWatch3
OH	Office of Hydrology
OI	Optimum Interpolation
OIQC	Optimum Interpolation Quality Control
OLR	Outgoing Longwave Radiation
OMBNN3	Ocean Modeling Branch Neural Network 3
OpenMP	A standard application program interface which supports multi-platform shared-memory parallel programming in C/C++ and Fortran on all architectures including Unix platforms and Windows NT platforms.
OPI	OLR Precipitation Index
OPTRAN	Optical Path Transmittance
OSO	Office of System Operations
PBL	Planetary Boundary Layer
PE	Processor Element
PoP	Probability of Precipitation
PQPF	Probabilistic Quantitative Precipitation Forecasts
PROD	Production
PROFCQC	Quality Control Module for wind profiler data.
QC	Quality Control
QPF	Quantitative Precipitation Forecasts
RAFS	Regional Analysis and Forecast System
RaOB	Radiosonde Observations
RAS	Relaxed Arakawa-Schubert
RASS	Radio Acoustic Sounding System
RDAS	Regional Data Assimilation System
RFCs	River Forecast Centers
RGL	Regional [Run]
ROI	Regional Optimum Interpolation
RPSS	Ranked Probabilistic Skill Score
RSM	Regional Spectral Model
RTNEPH	Real Time NEPH (cloud) Analysis
RUC	Rapid Update Cycle
SAMEX	Storm And Mesoscale Ensemble Experiment
SAS	Simplified Arakawa-Schubert
SBUV	Solar Backscatter Ultraviolet Instrument
SCAN	System for Convection Analysis and Nowcasting
SDS	Synthetic Data System
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SPC	Storm Prediction Center
SREF	Short-Range Ensemble Forecasting
SSI	Spectral Statistical Interpolation

SSMI	Special Sensor Microwave Imager
SST	Sea Surface Temperature
SSTA	Sea Surface Temperature Anomaly
SW	Short Wave
TAMC	Tangent Linear and Adjoint Model Compiler
TDL	Techniques Development Laboratory
TOGA	Tropical Oceans and Global Atmosphere
TOPEX	Ocean Topography Experiment
TOVS	Tiros Operational Vertical Sounder
TPC	Tropical Prediction Center
U.S.	United States
USGS	United States Geological Survey
USWRP	United States Weather Research Program
UTC	Universal Time Coordinated
UV	Ultraviolet
VAD	Velocity Azimuth Display
VAFTAD	Volcanic Ash Forecast Transport and Dispersion
VSDB	Verification Statistics Data Base
WAM	Wave Forecasting Model
WCRP	World Climate Research Program
WRF	Weather Research and Forecasting
WSFO	Weather Service Forecast Office
WFO	Weather Forecast Office
WMO	World Meteorological Organization
VSDB	Verification Statistics Data Base
WSR-88D	Weather Surveillance Radar 1988 (Doppler)
WVSS	Water Vapor Sensing System
1-D	One Dimensional
2-D	Two Dimensional
3-D	Three Dimensional
4-D	Four Dimensional
3D-VAR	Three-Dimensional Variational Data Assimilation
4D-VAR	Four-Dimensional Variational Data Assimilation

1. RESEARCH AND DEVELOPMENT IN NUMERICAL ANALYSIS AND PREDICTION SYSTEMS

1.1 Global Forecast Systems Development Activities

1.1.1 Analysis

NOAA-15 HIRS/3 and AMSU-A Radiances

In mid March 1999, the NOAA-15 HIRS/3 and AMSU-A radiances were added. In addition to assimilating new data, the implementation decomposed the bias of all radiance data into three components; a static bias correction, a weighted lapse rate correction which is basically a mean lapse rate over the simulated radiance observation, and a time dependent component. The impact of the NOAA-15 data is neutral to positive, with a greater impact in the Southern Hemisphere (Treadon, Derber).

IBM SP Conversion

The analysis code was converted to run on the IBM SP. Verifying the correctness of the conversion required explanations for each difference found. Large portions of the code were optimized and/or rewritten so that new T170 42 level version of the model would fit into its allotted time slot. The T170 was implemented on Jan 25, 2000. (Treadon)

The Multi-Processor Parallel (MPP) Operational SSI Analysis System.

The MPP system has been developed and implemented. It is designed and optimally tuned to obtain the best possible performance. It includes a high stable load balance scheme to be able to input any possible observations. The accuracy of the MPP system is much higher than the original non-MPP system and is limited only by machine limitations. The MPP version of SSI analysis system which includes Doppler wind observations has been completed and tested. The development of an MPP SSI Analysis System which uses mixed various resolutions is in progress. This should improve forecast quality and computational efficiency. (Sela)

Analysis on Physical Space

Numerical recursive filters have been applied to the task of convolving a spatial distribution of innovations with a smoothing kernel that is interpreted to be a covariance function of background error. The flexibility of using a recursive filter

to apply background error on a grid includes spatial variation of variance and correlation length and fully anisotropic correlations in three space dimensions. (Wu)

Targeted Observations

A quasi-operational adaptive observing program was established (Winter Storm Reconnaissance program, WSR). In this program, dropsonde data are collected in the northeast Pacific, using NOAA and USAF aircraft, with the aim of reducing forecast errors associated with significant weather events, identified in advance (Toth et al., 1999). The areas from which the observations are expected to produce the largest impact are identified with the Ensemble Transform (ET, Bishop et al., 1999) technique, developed in collaboration with Penn State scientists. The targeted data were found to have a significant positive impact on the quality of surface pressure, tropospheric wind, and precipitation forecasts in the areas of severe weather. (Toth, Szunyogh)

1.1.2 Atmospheric Model Development

IBM SP Conversion

Conversion of the global model to the IBM SP was a major project which required an enormous amount of time and manpower. There was a major emphasis on the message passing interface (MPI) for communication and portability. In favor of THREADING, OpenMP directives were added to the three main processes of the model in order to cut the communication among processors (multi-tasking). A scheme to enable the running the model with different grid resolutions in the dynamics and physics is close to completion. The model was also ported to an SGI Origin 2000.

Radiation

A major investigation of state-of-the-art radiation parameterizations for NCEP's atmospheric models has begun (Campana). The current short wave (SW) scheme (NASA, 1990's) appears to overestimate downward flux at the earth's surface. The current long wave (LW) scheme (GFDL, 1991) does not contain improvements made elsewhere in the 1990's. Interactions between NCEP and the following institutions are ongoing :

- NASA Goddard (Chou, etal). Tests have been made using the 1999 revised SW scheme. It includes enhanced absorption due to water vapor, CO_2, and O_2. Also being tested are improve-

ments to the aerosol parameterization, so that it can be restored to the operational scheme.

- Colorado State University (Stephens, Partain). A one column version of NCEP SW and LW radiation was passed to CSU. Comparison testing with other parameterizations is being made with atmospheric radiation measurements (ARM) data.
- GFDL (Ramaswamy, Schwarzkopf, Freidenreich). The new SW and LW codes are being brought to NCEP early in 2000.
- Atmospheric and Environmental Research, Inc. (Clough, Iacono, Mlawer,etc). The LW code is in-house and testing has begun.

(Hou and Campana)

Probabilistic Quantitative Precipitation Forecasts (PQPF)

A bias correction algorithm based on the ensemble forecasts was tested. Different levels of accumulated precipitation are predicted by using different percentile values associated with the distribution of ensemble forecasts based on past verification statistics. This method reduced the bias and it provides precipitation forecasts with better equitable threat scores(ETS)than the MRF control forecasts. (Zhu and Toth)

The Impact of Model Resolution on Ensemble Forecasting

A 10 member experimental, T126 global ensemble was run over a 30-day period(Szunyogh et al., 1999). The ensemble system benefitted from the increased horizontal resolution more than the single control forecast started from the control analysis. The biggest improvement occurred in days 1-3, however, additional improvements resulted from maintaining the high resolution out to 7 days. Consequently, the horizontal resolution of the operational ensemble forecasts will be increased to T126. (Toth)

MRF Model

The MRF has been modified to include any number of tracers (in addition to ozone). Experimentation with cloud condensate as a prognostic variable is underway (Moorthi). Cloud amounts and optical properties for radiation are determined diagnostically from the cloud condensate amounts. Convection as well as large-scale condensation are the sources of cloud condensate. The large-scale condensation and the precipitation scheme follows Zhao and Carr (1999).

Single Column Model

A single column model version of the NCEP MRF model has

been developed. This will enable programmers to evaluate and debug changes in the physics packages. It will also be useful in diagnosing model behavior (Moorthi).

Semi-Lagrangian Integration Technique

A version of the model now exists with a reduced Gaussian grid in order to improve efficiency and to prepare the grid environment for a possible Semi-Lagrangian integration technique.

Convection

The operational convection scheme (Simplified Arakawa-Schubert scheme) was combined with the variable cloud depth aspect of the Relaxed Arakawa-Schubert scheme. A preliminary study indicates improved tropical moisture distribution in the upper troposphere. In addition, there is enhanced precipitation in the western Pacific, where the current scheme lacks precipitation in the region. The impact of this change to North America summer precipitation forecast skill and to Atlantic hurricane forecasts is currently being testing (Pan, Hong and Moorthi).

The Relaxed Arakawa-Schubert scheme Version 2 has been developed and is available for anyone interested. A NOAA technical report documenting the details of this version of RAS has been published (Moorthi).

Surface Processes

New orography global data sets were constructed with a grid spacing of 1 km. These datasets are generalized to the current Global Spectral Model resolution (t170/1x1 degree) and tested including effects from gravity wave drag and other surface processes. Implementation is expected in 2000 (Hong).

1.2 Mesoscale Forecast Systems Development Activities

1.2.1 Operational Implementations

May 13, 1999 - The mass-wind balance in Eta 3D-VAR was corrected. The Eta 3D-VAR analysis was changed to correct parameters influencing the balance between the analyzed wind and mass fields. In the November 1998 change, these parameters were adjusted so that the analysis drew more closely for radiosonde data, but this created a weaker balance between the mass and wind fields. This occurred primarily in regions with mostly single

level or single type data (e.g. satellite temps, flight level aircraft data, satellite cloud-drift winds). In addition, the new 3D-VAR code now inputs and outputs 2-D files. With this change, all the conversion codes from 2-D to 1-D and 1-D to 2-D are no longer needed.

June 7, 1999 - BUFR breakout files were elevated to production (PROD) status.

June/July 1999 - The script which retrieves the AVN boundary conditions for the 80 km BACKUP Eta on the J-90 was improved.

July 13, 1999 - Minor adjustments/corrections for wind and moisture analysis in the Eta 3D-VAR were implemented: corrected a loop index in the wind super-ob routine, relaxed a too stringent limit on the magnitude of high level moisture increments and corrected the procedure for getting guess moisture below the guess terrain.

July 26, 1999 - Fixes were made to the HYBNCEP module to fix errors in the moisture fields used in the Rapid Update Cycle (RUC) boundaries. The primary error was that saturation vapor pressure was calculated using virtual temperature rather than temperature. The second error was that the saturation vapor pressure at temperatures below -15 deg C were calculated with respect to ice instead of water. The impact of the fixes to these errors is to eliminate much of the erroneous precipitation along the RUC boundaries over warm oceans and slightly reduce some of the excessive areal coverage of RUC precipitation over warm oceans. Also eliminated was the underestimated boundary mixing ratios where the temperature was less than -15 °C. Examples of 12 hour RUC precipitation before and after the change may be viewed at http://maps.fsl.noaa.gov/ruc_bc_fix.html.

Sept 28, 1999. The conversion and implementation of the Eta and RUC-II codes on the new IBM SP machine was completed. The effort involved considerable debugging and comparison of test output to Cray output.

After the fire, from 00 UTC 28 Sep to 00 UTC 18 Nov, the 80 km/ 38 level Eta was run as the operational model at 00 UTC and 12 UTC. The version had a 3D-VAR analysis but no Eta Data Assimilation System (EDAS). It ran within the standard time window and produced identical output as the C-90 run. It was timely, but, of course, less accurate due to its degraded resolution. The new IBM SP was not available for backup because it was in transit to its new home in Bowie, MD. Since 12 UTC 18 Nov the operational 32-km Eta/EDAS has been produced on the

IBM/SP.

The RUC2 was also effected by the fire. With local resources only the old 3-hourly 60 km RUC1 could be run on NCEP's J-90. The plans for catastrophic backup were accelerated. Effective 1 Oct, FSL shipped their hourly 40 km MAPS runs directly to OSO and served as the RUC2 backup. A summary of the differences between the FSL MAPS run (the RUC2 backup) and the NCEP RUC2 can be found at http://maps.fsl.noaa.gov/rucbackup_diff.html.

Emergency backup plans with the Air Force Weather Agency (AFWA) were accelerated. They performed a CONUS run with MM5 at 06 UTC and 18 UTC. It was decided to use the MM5 as the backup to NCEP's off-time runs and use the MM5 as complementary runs to the Eta-80 backup runs at 00 UTC and 12 UTC. MM5 36 km grids were shipped to an OSO workstation where a version of Eta's Product Generator code produced exact Meso Eta look-alike products for dissemination to the NCEP's AWC, SPC and HPC and through the AWIPS SBN to the NWS field offices.

November 18, 1999 - Hourly RUC2 and 4-per-day Eta were re-established and elevated to PROD status on the IBM SP in Bowie. This included runs of the cycled EDAS (using 12 hours of pre-forecast period observations) prior to the 00 UTC, 06 UTC, 12 UTC, and 18 UTC runs.

The data processing scripts for the IBM version of the RUC2 now contain observation quality-control modules: CQCBUFR (for radiosonde data), CQCVAD (for VAD wind profiles from WSR-88D radars), and PROFCQC (for wind profiler). The programs ran routinely for the other NCEP analysis runs but they took too long to run on the Cray and still have the RUC2 run within its time window.

December 6, 1999 - A RUC2 fix was prepared to correct a code error resulting in the wrong units for canopy water. The fix was put into operations at NCEP at 1600 UTC.

1.2.2 Eta Model Development

Four-per-day Eta-32 Runs

The implementation of the uniform 4/day Eta-32 on the IBM SP in mid November included the extension of the 0600 and 1800 runs out to 48 hours. The 22-km / 50-level setup has been delayed because of a problem with the memory size of the current postprocessor. At the higher resolution, the single-threaded version of the code will not fit on the Winterhawk nodes of the

IBM and runs too slowly on the Silver nodes. (Rogers, Black) Therefore, a version was constructed that used the MPI paradigm in that code. (Tuccillo, Black, Rogers)

Scalable Eta Model Code

The scalable version of the Eta is now complete. This version is scalable in that it runs well on any number of processors (1 to the max) and it also runs well on any platform (Origin, HP, SGI, Linux, etc.). The conversion was completed prior to the move of the IBM to Bowie and 4/day runs were implemented November 15, 1999. (Black, Tuccillo, Abeles)

Kain-Fritsch Convection

Efforts continue to develop, refine, test and evaluate improved treatments of sub-grid scale convection ant its connection to cloud, precipitation and micro-physical processes in the Eta Model. NSSL is using a workstation version of the Eta Model (Baldwin) to make their daily runs of a small domain within the Eta-32 with the Kain-Fritsch convection scheme and other model changes. In general, the Kain-Fritsch scheme shows a slight improvement over the operational scheme in the cold season, where the operational model is generally better in the warm season (Baldwin, Kain, Mitchell, Manikin).

The NCEP Nonhydrostatic Meso Model

The Janjic nonhydrostatic capability has been fully tested and has reproduced classic results for cold bubble, warm bubble and nonlinear mountain wave cases and has been used in sigma mode to simulate the Wasatch Mountain downslope wind storm. There are five related papers on line at http://www.emc.ncep.noaa.gov/mmb/papers/index.html. The Janjic nonhydrostatic capability is the final choice for the relocatable nested system. Further large domain high resolution testing remains to determine which vertical coordinate system will be used sigma or the step mountain eta. The nonhydrostatic model appears to be computationally robust at all resolutions, and efficient in NWP applications. With the current coding, there is only a 30% increase in required computer resources. At lower resolutions, the nonhydrostatic version of the model reproduces the results obtained using the hydrostatic model. (Janjic)

The impact of the nonhydrostatic dynamics appears to be weak at the horizontal resolutions on the order of 10 km. A visible impact was detected on simulated heavy orographic precipitation maxima when using a resolution of 4 km or less.

Also, the nonhydrostatic deviation of pressure made a nontrivial small scale contribution to the pressure gradient force in places. (Janjic, DiMego)

GCIP

Over the past several years, EMC has joined with NWS hydrologists in the Office of Hydrology (OH), land-surface remote sensing experts in NESDIS, and numerous GCIP and GEWEX investigators to develop, test, and operationally implement a series of advancements to the land-surface and hydrology physics of the NCEP mesoscale Eta model and its associated Eta-based 4D-VAR Data Assimilation System (EDAS). Since NCEP operationally implemented continuous cycling of soil moisture and temperature in the coupled EDAS on 03 June 98, no nudging of soil moisture has been necessary as no strong signals of undue soil moisture drift have yet emerged.

During 1999 the focus was on expanding capabilities to use GCIP-sponsored GOES-based satellite retrievals of land-surface skin temperature and traditional shelter observations of 2-m air temperature and humidity to monitor drift, which is now done on a systematic monthly basis over 13 sub-regions of the U.S. The continuously cycled soil moisture in the coupled Eta/EDAS is obviously sensitive to whatever systematic biases exist in the coupled EDAS accumulated precipitation patterns. (Mitchell, Tarpley) To eliminate such biases, final testing was completed of the prototype EDAS hourly precipitation assimilation system, which uses the GCIP-supported, realtime, national, hourly, 4-km Stage IV radar/gauge analyses of precipitation http://www.emc.ncep.noaa.gov/mmb/gcp/htmls/hdpprec.html . (Lin, Mitchell, Baldwin)

Important companion research and development was carried out in complimentary initiatives in UNCOUPLED land-surface modeling. These included a) physical refinements in the areas of frozen soil, snowpack, ground heat flux, canopy and atmospheric resistance, b) a major new multi-agency initiative (with NWS/OH, NESDIS/ORA, NASA/GSFC, and several universities) in a U.S. domain, realtime, hourly, 15-km uncoupled Land Data Assimilation System (LDAS http://ldas.gsfc.nasa.gov/), and c) public release of a "community" version of the NCEP land-surface model, now formally called the "NOAH LSM". During this past year, about one dozen external principal investigators have requested and obtained the community NOAH LSM. The multi-agency LDAS initiative is summarized in an article in the November 1999 issue of the bimonthly GEWEX Newsletter. (Mitchell, Lin, Marshall, Rogers, Ek, Lohmann, Manikin, Grunman)

Correction of Biases in Convective Scheme

In anticipation of an early 2000 implementation and while efforts were being concentrated on the conversion to the IBM, a parallel system was maintained on the Cray that was testing a set of changes designed to reduce two well known biases in the convection: 1) too little convection over elevated terrain and 2) too much precipitation along the Gulf and Mid-Atlantic coasts. The solution to 1) was to code the several criteria for convective onset to be in terms of pressure normalized be the surface pressure. This eliminated what acted like a 'terrain penalty' in the original coding. The coastal bias was addressed by unifying the deficit saturation pressure (DSP) profiles between land and sea. Long term evaluation had determined the cause to be onshore trajectory air, which after long fetch was in balance with the moist sea profiles, produced rain when crossing the coastline and being then compared to the drier land profiles. Sea profiles are now used everywhere. This 80 km parallel system was run without interruption until the fire in late September 1999. Results can be found (by region) at http://sgi62.wwb.noaa.gov:8080/CONV/ and are discussed in the TPB and CAFTI presentation at:
ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/etatpb/eta60tpb.htm
ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/etacafti/index.htm
(Manikin, Gerrity, Baldwin, Rogers, Mitchell, DiMego)

1.2.3 Eta Data Assimilation System

Diabatic Initialization

Retrospective tests of the refined version of hourly precipitation assimilation (with further moisture adjustment based on Pobs-Pmod) using the new operational 3DVAR and the new convective package have been completed for both warm season and cool season. Results show many instances of significant positive impact for 0-6h, 6-12h and 0-24h forecast as well as during the data assimilation period as well. This capability needs to be incorporated in the new Meso Eta Model code using MPI. See http://www.emc.ncep.noaa.gov/mmb/papers/lin/pcpasm/paper.html
(Lin)

Diabatic Initialization with GOES Cloud Top Pressure

Diabatic initialization efforts have continued this year in collaboration with Jim Jung of NESDIS. GOES cloud top pressure information is used to eliminate cloud erroneously forecast in the Meso Eta and to build cloud where it is absent. A duplicate EDAS system to NCEP's 80 km parallel is used to test

impact of the procedure. Several aspects of the grid-scale cloud scheme have been identified that contribute to a lack of significant impact so far from the cloud adjustments. A modified cloud package is next to be tested. (Jung, Zhao, Black, DiMego)

3D-VAR Assimilation of Precipitation Data

The 3D-VAR algorithm for the Eta model has been updated to assimilate hourly rain gauge and precipitation data. This algorithm employs the column precipitation model and corresponding adjoint. Some data assimilation experiments were performed, indicating a positive effect of assimilation of precipitation data. At present, the algorithm is developed for a single node of the IBM SP computer. It is also a part of Regional Reanalysis Project. (D. Zupanski, Parrish)

Soil moisture assimilation

A data assimilation scheme is being developed (1D-VAR at present, but 4D-VAR in the future) for assimilation of soil moisture related variables, such as satellite skin temperature. The adjoint of the land-surface package is a necessity for this approach. (D. Zupanski, Grunmann and Mitchell)

4D-VAR Development

The Eta 4D-VAR system was tested in early 1999 on the Cray C-90. The conversion of the code to the new IBM SP parallel computer was completed in November. D. Zupanski has been developing the adjoint for the eta model and he is applying the automatic adjoint generator (R. Giering's Tangent linear and Adjoint Model Compiler (TAMC)). This generator however, does not deal with the parallel interface routines (MPI calls)for which adjoint code was developed. The adjoint of the Eta model dynamics is now completed and being used in real data assimilation tests. The adjoint of the model's physics is being developed and tested. The entire 4D-VAR algorithm has been parallelized. In the future the remaining physics in the adjoint model will be included. Also, a mesoscale version of the 4D-VAR system will be developed which will be capable of assimilating a variety of data, such as precipitation, Doppler radar winds, cloud information etc. In addition, ways to correct the model bias during the forecast time will be examined. (D. Zupanski, M. Zupanski, Parrish, Rogers and DiMego)

Regional Reanalysis

This effort is funded by NOAA/OGP and is preparing a

system capable of performing a 22-25 year reanalysis for North America. The regional reanalysis (RR) scripts were run for one month (July 1998) as a pilot project on one of the Cray J-90s. A one month pilot containing precipitation assimilation (procedure devised by Ying Lin) was also run. Pilot results showed improvement in precipitation with little effect on state variables. This was similar to results of Lin's precipitation assimilation tests. The system was moved to an SGI Origin 2000 and the Message Passing Interface (MPI) version of codes were tested for the control system. There is an RR web site under construction. See http://sgi62.wwb.noaa.gov:8080/RREANL for the first ten days of the July 1998 pilot runs. Also see ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/regreanl/sld001.htm for recent status. The following data is being gathered and formatted for use in future RR runs:

- TOVS 1-b radiance data
- Hourly precipitation data
- Comprehensive Ocean and Atmosphere Data Set(COADS)
- SSM/I satellite data for ocean surface wind speed and precipitable water
- Air Force snow depth
- Air Force RTNEPH cloud data

(Kalnay, Mesinger, Shafran, Lin, D. Zupanski, Parrish, Rogers, DiMego)

1.2.4 Eta-10 Support for Western United States

No runs were accomplished during 1999, but see section 4. to see plans for the Salt Lake City Olympics Plan.

1.2.5 Saudi Eta

A special run of the Eta model centered over Saudi Arabia has been set up to support Saudi forecaster training within NCEP. It was run once daily at 0000 UTC in an 80 km/ 38 level configuration between May 1998 and October 1999, and more recently has been run twice daily with 48 km grid spacing and 45 vertical levels. The model code is identical to the operational Meso Eta run for North America, although the Eta Data Assimilation System (EDAS) in the Saudi Eta assimilates data less frequently (6 hourly versus 3 hourly) due to the comparatively small volume of data available over the region. The Saudi EDAS uses a global model first guess for atmospheric fields, while a forecast from the previous EDAS cycle initializes soil temperature and moisture (“partial cycling” in EMC terminology).

1.2.6 Other Activities

Exportable Workstation Version of Eta Model

An easily reconfigured, multi-platform version of the Eta Model was made available in May 1999. This system allows the user to run the Eta at their own site assuming they have access to a UNIX/LINUX workstation and the ability to download real-time data from NCEP models. The package was designed to be a self-contained modeling system. It includes the Eta model, scripts and codes to obtain data from operational NCEP models and interpolate them to the user domain for initial and boundary conditions. It also includes codes to post-process the user's model output into GRIB format. This version was designed with flexibility in mind; changes to model location, resolution, and domain size are readily made. This flexibility allows the user to address a modeling problem appropriate for their available computing power, and makes the Eta model a more viable tool for the research community. Rozumalski of COMET has built upon this capability and has released a version for the NWS SOO's. More information can be found at http://sgi62.wwb.noaa.gov:8080/wrkstn_eta/ or ftp://ftp.ncep.noaa.gov/pub/emc/wrkstn_eta/. (Pyle, Baldwin, Snook, Rozumalski, Rogers).

NAOS (North American Observation System)

NAOS seeks to determine whether removal of radiosondes scattered throughout the US (where nearby airports had frequent ACARS ascent & descent reports) had any effect on the forecast, and whether the function of the radiosondes could be picked up by the aircraft (Lord, Shafran, Tracton, Zhu). Verification of 3 Eta runs done in 1998 were completed. The three runs were the control run, a run removing 14 radiosondes, and a run removing 14 radiosondes plus surrounding aircraft. The results suggested that the removal of radiosondes changed the analysis slightly, but a look at the root-mean-square (RMS) errors show that the impact through the 48 hour forecast was minimal. Previously, experiments were run on the MRF by Yuejian Zhu, and FSL ran experiments with the RUC. Results can be found at http://sgi62.wwb.noaa.gov:8080/NAOS/

Picket Fence

Picket Fence is a data assimilation experiment where a series of additional radiosondes were installed along the US West Coast, creating a "Picket Fence" of observation sites. These several sites, in addition to the standard NWS radiosondes along

the West Coast, took observations every 3 hours instead of 12. The reason for this is to see if the forecast in the interior of the US can be improved by better spatial and temporal resolution of observations catching systems coming in from the data-poor Pacific regions. All four IOP's were completed in early 1999 (after several false starts due to changing 3DVAR). The Air Force snow depth was used instead of reanalysis snow depth. Overall, only one of the IOP's showed any positive impact. It should be noted that observations for most part were not in an area of strong dynamics. Results were shown at the USWRP workshop in Boulder in Spring 2000 and a paper is in the process of being written. Results for IOP3 and IOP4 as well as summary verification statistics for all four IOP's can be seen at http://sgi62.wwb.noaa.gov:8080/PFENCE/. (Shafran, Hirschberg, Elsberry, Ritchey, DiMego)

MERGE

At the request of the FAA and the Air Transport Association, NCEP has developed the ability to create a set of WAFS grids for North America which combines the RUC, Eta and AVN grids. Now designated MERGE (short for Merge of Eta RUC and Global-AVN by EMC). This product is produced every 3 hours or 8 times per day since January 2000 and is made available for ftp download from the OSO server. For more information see ftp://ftp.ncep.noaa.gov/pub/emc/wd23bk/wafs/wafs.html. (Kistler)

1.2.7 Short-range Ensemble Forecasting (SREF)

To be consistent with resolution of regional models, a regional-model-based "regional breeding" scheme was tested and implemented to generate initial perturbations for SREF. This replaced the old scheme which is a hybrid breeding cycle generated by combining both the regional and global models. The SREF system has been converted from Cray to IBM SP and tested successfully on IBM SP. For more information, please see: http://lnx48.wwb.noaa.gov/SREF/SREF.html. (Tracton)

1.2.8 Rapid Update Cycle

The lion's share of activity this year was to accomplish the code conversion and the data ingest changes necessary to implement a timely RUC on the IBM SP. FSL runs of their MAPS system were used for backup during the fire. Check out their site at http://maps.fsl.noaa.gov (Manikin)

1.3 Climate Model

Development of NCEP Climate AGCM

A major ongoing effort during 1999 is the development of a new global climate atmospheric model. This model is expected to replace the current Cray version of the NCEP climate model for seasonal climate prediction. This is motivated by progress in improving physical parameterizations in atmospheric GCMs during the past 5 years and by the fast evolving computing technology. The new climate model is portable, scalable and plug compatible. Thus, it will facilitate collaborative research and development activities with the research community toward accelerated development and improvement of operational climate forecast system at NCEP.

Significant progress has been made during 1999. Presently, more than twelve 50-year AMIP type simulations at T42L28 resolution on SGI/Origin2000 and IBM SP computers have been completed. The test shows that this model has near linear scalability from a small number of processor elements (PEs) (4-8) up to 512 PEs at T126 and T170 spectral resolutions.

Improving Estimates of Salinity Variations on Seasonal to Interannual Timescale

The ocean data assimilation system at NCEP provides initial conditions for the ocean component of the coupled ocean-atmosphere model that is used for seasonal to interannual forecasts. In the last year, the system has been extended to correct salinity as well as temperature through the assimilation of in situ temperature data and satellite altimeter data (Vossepoel and Behringer, 1999). The present scarcity of subsurface salinity data means that the salinity corrections must be deduced from other data. This is accomplished statistically through a set of joint empirical orthogonal functions (EOFs) that tie salinity fluctuations to variations in temperature and sea surface height (Maes, et al., 1999). Recent experiments, comparing the new system with the old, show that the corrected salinity variability can alter the sea surface height difference across the equatorial Pacific by as much as 10 cm. Corresponding changes in the strength of the equatorial undercurrent are as large as 25 cm/sec.

1.4 Ocean Forecast Systems Development Activities

1.4.1 Marine Meteorology

A completely new neural network algorithm (OMBNN3) has

been developed for processing the SSM/I brightness temperatures to derive geophysical parameters over the oceans. This algorithm provides simultaneous retrievals of the ocean surface wind speed and columnar water vapor and liquid water. The wind speed retrievals produced by the OMBNN3 are found to be far superior than those obtained from other available algorithms under all weather conditions and wind speed ranges. Assimilation experiments using only the wind speed retrievals from OMBNN3 showed that these winds provided better analyses than the use of the current SSMI operational algorithm. Based on that result, routine assimilation of OMBNN3 based wind speed data was implemented into the global atmospheric model since last year. The ocean surface wind sped, columnar water vapor and liquid water fields derived from OMBNN3 are now available on the OMB home page for the Northeast Pacific and the Northwest Atlantic ocean every six hours, along with the ERS2 scatterometer wind data reprocessed by NCEP, ocean ship and buoy data, and the ocean surface pressure analysis from the GDAS. (Yu, Gemmill, Krasnopolski)

The Eta model is a limited area model which was designed for improving mesoscale forecasts of the continental United States, so that its domain over adjacent ocean is somewhat limited. Since SSM/I wind speed data are available only over the ocean, it is important to determine how much impact these data have on the Eta forecasts. Assimilation experiments with the EDAS using high resolution (25km) SSMI retrievals from the OMBNN3 have been conducted and the preliminary indications are that these data have a better impact on the model performance than the current operational retrievals provided by the Shared Processing arrangement. (Yu)

Several NSCAT studies were made this year, to determine the impact between the fast delivery data and the science data. Although, there were differences in both wind speed and direction between the two data sets, the impact of the data on analyses and forecasts were almost identical. There was a small positive impact in the southern hemisphere and almost none in the northern hemisphere. (Peters)

1.4.2 Ocean Wave Forecast Models

Efforts had been underway during the last few years to replace the operational WAM model with a new third generation model with improved numerics and physics. The new model, NOAA/NWW3, contains a more accurate finite difference scheme for wave propagation, a new formulation of wave generation developed by Chalikov and Belevitch, and a new formulation of wave

dissipation by Tolman & Chalikov. The winds used to drive the model are obtained from the NCEP's AVN forecast model. Global wave forecasts produced by the new model using a 1.0 x 1.25 degree latitude/longitude grid have been tested against the operational WAM. Evaluations, using buoy and altimeter data, have shown that the NWW3 model forecasts better swell both in mid-latitudes and in the tropics resulting in improved forecasts of the magnitude and timing of peak wave events. The model has now been approved for implementation on NCEP's new IBM machine. Particular attention has been given to modularity and portability aspects in developing the model code. It has been running as an internal operational model and the model code and its daily output fields have been made available on the branch's web page during the last year.

Two new regional wave forecast models based on the NWW3 model have also been developed for the Western Atlantic region which includes approximately the western half of the Atlantic and the Gulf of Mexico and for the Alaskan region which includes the Gulf of Alaska and the Bering Sea. These regional models use a grid resolution of 0.25 degrees in latitude and longitude. Wave conditions on the open boundaries of this model are provided by the global NWW3 model.

1.4.3 Coastal Ocean Forecast System (COFS)

The Princeton Ocean Model is currently being used to develop COFS for operational use. The model domain extends from 27N to 48N, and from the east coast out to 50W. The system predicts the three dimensional fields of temperatures, salinities and currents as well as the surface water levels. The model is coupled to NCEP's high-resolution Eta atmospheric forecast model which provides surface fluxes of heat, moisture, and momentum to the ocean model to produce nowcast and 24-hour forecast ocean fields. Climatological data for temperature, salinity, and volume transport provide forcing along the major southern and eastern open boundaries. Data assimilation using satellite retrievals of SST and in situ data from buoys following the technique of Derber and Rosati (1989, JPO, 1333-447) was implemented last year along with a procedure to project the SST changes into the oceanic interior using a constraint introduced by Chalikov and Peters (1997). Systematic validations conducted during the past year show that the forecasts of SST are significantly improved with the inclusion of this data assimilation.

NCEP participated in a Coastal Marine Demonstration Project (CMDP), supported by the National Ocean Partnership

Program, along with several participants from other NOAA elements, universities, and private sector. The purpose of the demonstration is to study the feasibility of producing high resolution marine meteorological and oceanographic analysis and forecast products that would be useful to the maritime community. In order to conduct this demonstration, the area of the Western Atlantic Ocean between 32 to 42 N latitude and off the coast to 70 W longitude including the Chesapeake Bay has been chosen and a selected group of users were chosen to receive the forecast and analysis products for evaluation. As a result of the Coastal Marine Demonstration Project, a new assimilation package from Princeton for assimilating altimeter data from TOPEX was implemented and has shown positive impact in specific cases where some of the Gulf Stream features were recovered. NCEP provided sea surface temperature, surface salinity, and surface currents from COFS along with surface winds, waves, and visibility over the chosen domain for the demonstration. The first demonstration took place in June-July, 1999 and a second one is scheduled for February-March, 2000. The results of the first demonstration are being evaluated.

In view of the lack of useful information from climatology on the lateral open boundaries on the required space and time scales for the COFS effort, development of a basin scale ocean model is continuing. This will enable us to provide the necessary boundary conditions for any limited area domain off the coastal areas of the US in a manner analogous to limited area numerical weather prediction models.

1.4.4 Sea Ice Analysis and Forecasts

The Sea Ice Drift forecast model was extended to 16 days, after the Anchorage forecast office reported that the guidance is useful even at that range. This guidance enables them to provide forecasts over a longer period.

Two sea ice concentration fields based on satellite-only analysis are made available operationally to the users - one on a 25.4 km and the other on a 0.5 degree resolution grids. This information is also made available on the GTS for use internationally. The sea ice fields on 25.4 km resolution are typically used by the sea ice analysts at NIC, Anchorage forecast office, etc. The product on 0.5 degree latitude-longitude grid is being used by NWP centers. Even in the 25.4 km resolution product, the near shore coastal zone and inland lakes are not resolved due to the low resolution channels used in the analyses. Work initiated this year suggests that 12.7 km analysis, based on the SSM/I 85Ghz channel, should be practical and data for

pursuing this study are now being captured. A preliminary evaluation shows that the ice concentrations near the Aleutians Island chain and in large North American lakes appear to be more accurately resolved in the 12.7 km analyses.

Sea ice climatology has long been a question for both model verification and for field operation guidance. The question arises because, although there are many sources for ice cover for a given day or month, there is currently no reliable information available on climatological 'normals' by days or months. A first cut sea ice climatology was assembled in FY 1999 from the 90 year Arctic and 18 year Antarctic history from Chapman and Walsh (1992). This first cut illustrated some interesting features, including the importance of defining 'climatology' for sea ice, which will be pursued in FY 2000. Of particular interest is the possibility of long range statistical prediction of the ice cover.

2. RESEARCH AND DEVELOPMENT RESULTS FOR APPLICATION OF NWP PRODUCTS

2.1 General Development Techniques

The Techniques Development Laboratory (TDL) conducts applied research in techniques for improving weather forecasting and product generation (Glahn). Objective methods of predicting basic weather elements needed in public and aviation forecasts are developed by statistical interpretation of numerical weather prediction model output. The statistical guidance is designed to initialize a digital database at the local NWS forecast office. Once the digital database is established, the local forecaster can use interactive computer techniques to prepare various forecast products. Techniques applicable to the prediction of storm surge caused by tropical or extratropical cyclones are also developed through the use of dynamical storm surge forecast models. Finally, methods of objectively predicting mesoscale convective weather events at very short-range projections are developed by analyzing and interpreting remote sensor observations such as WSR-88D radar reports, satellite observations, profiler winds, or lightning detection reports.

2.1.1 Objective Weather Prediction

Short-Range Weather Forecasting

MOS-2000 is a new system of data formats and software designed to produce interpretive statistical guidance in a more efficient manner from the latest versions of NCEP models (Dallavalle). We are using this system to develop a complete package of MOS guidance from the Aviation (AVN) run of NCEP's Global Spectral Model. In the first phase of the new AVN-based MOS system, we will generate guidance for over 1000 sites in the contiguous U.S., Alaska, Hawaii, and Puerto Rico. A complete package of guidance will be developed for the 0000 and 1200 UTC initial times of the AVN; a partial package will be developed for the 0600 and 1800 UTC initial times. We have completed development of warm (April - September) and cool (October - March) season MOS wind forecast equations for all four forecast cycles. These regression equations will be used to predict the 10-m wind speed and direction valid every 3 hours from 6 to 72 hours after initial model time. MOS equations to predict the maximum/minimum (max/min) temperature, 2-m temperature, and 2-m dew point for projections out to 72 hours after both 0000 and 1200 UTC have also been developed for the cool season. In tests on independent data, we found that the accuracy of the new AVN MOS wind and temperature guidance was generally equal to or

greater than the accuracy of the operational MOS guidance based on the Nested Grid Model (NGM). We are now developing and testing equations to predict the probability of categories of precipitation amount, precipitation type, ceiling height, total sky cover, thunderstorms, severe weather, visibility, and obstruction to vision.

Medium-Range Weather Forecasting

Development of updated MOS guidance based on NCEP's Medium-Range Forecast (MRF) model for projections out to 8 days in advance continued (Erickson). A proposal for an updated suite of MRF MOS guidance was developed. For the first time, forecasts of 2-m temperature, 2-m dew point, precipitation amount, and thunderstorms will be provided in the medium range. Other predicted weather elements such as wind speed and sky cover are being redefined to better serve the forecast community. The new guidance will be available for over 1000 stations, a significant increase from the current 255 stations. Equations to predict max/min temperature during the warm season were developed. The cool season temperature development is also nearing completion. Experimental equations to predict the probability of precipitation occurrence and amount were developed, and test forecasts made on independent data were verified for both the warm and cool seasons. All tests indicate that the new system will provide skillful guidance. Plans to provide max/min temperature, 2-m temperature, and 2-m dew point forecasts to support the NWS 3-10 day threat assessment product were also established.

Severe Weather Prediction

We continued our effort to develop new MOS thunderstorm and severe local storm probability forecast equations for projections out to 60 hours from the Eta model and out to 72 hours from the AVN run of the Global Spectral Model (Reap, Hughes). Lightning data and severe thunderstorm reports were obtained and packed into the MOS-2000 format for use as predictands. Monthly relative frequencies of thunderstorms and severe weather have been calculated from 5 years of data. Software was modified to prepare data, to compute additional predictors, and to incorporate recent improvements in the quality of the observed cloud-to-ground lightning data. A new version of TDL’s three-dimensional trajectory model based on wind forecasts from the Eta model was also developed and tested.

2.1.2 Local Techniques Development

Multi-sensor algorithms for 0-3 h QPF and cloud-to-ground lightning forecasts have been developed and implemented in an experimental mode with output available on the TDL Home Page (Kitzmiller). The QPF algorithm produces the probability of heavy rainfall and a forecast of the maximum rainfall amount within square regions 40 km on a side. Development of an enhanced national-scale 10-km radar reflectivity analysis was completed. This mosaic will be utilized in AWIPS applications and as basic information to field forecasters.

Thunderstorm Identification and Forecasting

Version 2.0 of the System for Convection Analysis and Nowcasting or SCAN was prepared for AWIPS Build 5 (Smith). The major new functionality introduced was that of the National Severe Storms Laboratory's Warning Decision Support System. Software alpha-testing of SCAN 2.0 was initiated at the NWS forecast office in Little Rock, Arkansas. Work began with members of the Office of Hydrology on providing automated flash flood monitoring and prediction functionality in SCAN.

Local AWIPS MOS Program (LAMP)

The LAMP system was prepared for AWIPS Build 5. This included integration of the LAMP QPF sub-system and preparation of a version to be run at the NCEP centers (Ghirardelli). The LAMP system was also enhanced by adding variable analysis grid resolution and better quality control of input METAR observations.

Heavy Precipitation Forecasting

A statistically-based model that produces local updates of the centrally-generated QPF's for the contiguous U.S. has been running experimentally for the past two years (Charba). The LAMP QPF model produces probability forecasts of various categories of precipitation amount on a 20-km grid for 1-, 3-, and 6-h periods out to 22 hours in advance. Based on the probabilities, the model also produces best category and expected precipitation forecasts. The real-time QPF products are being made available to WFO's for evaluation. During the past year, the robustness of the experimental system was improved, the model forecasts were added to the TDL Home Page, and the system was prepared for AWIPS implementation.

2.1.3 Marine Environmental Prediction

Hurricane Storm Surge Forecasting

The dynamic hurricane (tropical cyclone) storm surge model (SLOSH) has been applied to the United States' Gulf of Mexico and Atlantic coastlines; the Virgin Islands; and the islands of Oahu, Hawaii; Guam; and Puerto Rico (Shaffer). The model considers inland routing of sea water, overtopping of barriers, flow of water through gaps between barriers, flow through rivers, and channels. A hurricane wind model is embedded within the SLOSH model. SLOSH terrain for updated U.S. basins is now obtained from the USGS's 30 meter by 30 meter digital elevation model. The terrain data are processed by using a Geographic Information System (GIS); output is checked by using raster-scanned quadrangle maps. Levees, coastal roadways, and sub-grid scale ridges act in the model as barriers to surge flow. Elevations for these features are extracted from diverse sources and incorporated manually into the model’s database. Completed basins are turned over to NCEP's Tropical Prediction Center for operational forecasting and for simulation studies to use in hurricane evacuation planning.

Analyzed hurricane wind fields produced by NOAA’s Hurricane Research Division (HRD) have been tested in place of the SLOSH parametric wind field. These analyzed wind fields are being produced experimentally on a 3-h schedule as a hurricane approaches U.S. landfall. The HRD technique blends hurricane winds measured from various platforms (aircraft, buoy, ship, surface, etc.) and with differing averaging times, collected over an extended time period, to produce a consistent surface wind field. For Hurricane Floyd, we found little difference between SLOSH surges produced by analyzed winds and those produced by the standard SLOSH parametric wind model when the best definitions of the hurricane’s track, size, and intensity were used.

Extratropical Storm Surge Forecasting

The SLOSH model was adapted to predict storm surges generated by extratropical storms (Chen). Unlike SLOSH which has an embedded wind model, the extratropical storm surge model is driven by wind and pressure forecasts from the AVN model. Most of the extratropical storm surge model's physics remain the same as that of SLOSH, but overland flooding is not considered. The model is now run twice daily for the U.S.’s East Coast, the Gulf of Mexico coast, the Northwest Coast, Norton Sound in Alaska, and the Arctic Ocean coastline of Alaska. Forecasts are being archived and evaluated.

Coastal Wave Forecasting

Two parametric hurricane wave models were developed for predicting the maximum waves generated by hurricanes (Wu). Using the existing SLOSH wind model, an ocean wave model can extend the hurricane wave field to a two-dimensional horizontal plane. To evaluate the wave impact at the coastline, a random breaking-wave model calculates the breaking waves and their associated set-up and run-up for a plane beach. An integrated coastal wave system which includes hurricane wave prediction and coastal wave transformations will complement the storm surge forecasts at coastal sites.

2.1.4 Local Products Development

Product Generation

TDL developers continued to support forecasters at the NWS Weather Forecast Office (WFO) in Norman, Oklahoma as they used the alpha version of the Interactive Forecast Preparation System (Ruth). Applications in the Interactive Forecast Preparation System (IFPS) were enhanced to support forecasts to projections of seven days and to allow the forecasters to easily customize IFPS. Site-defined "wildcard" elements (e.g., snow on grassy areas) are now supported in gridded, matrix, and worded forecasts. The alpha version is being deployed to two additional forecast offices, including a marine site, for testing prior to national training and deployment of IFPS next year.

3. ANALYSIS-FORECAST SYSTEMS IN OPERATIONAL USE DURING 1999

3.1 The Eta Model Runs

The Eta Model is named for the Greek letter used as the symbol for its vertical coordinate. This eta coordinate system is a simple variation of the commonly used sigma coordinate system. Both coordinate systems are normalized and pressure-based: the eta is normalized with respect to the mean sea-level pressure whereas sigma is normalized with respect to surface pressure. Sigma surfaces are terrain following and can be quite sloped, whereas eta coordinate surfaces are nearly horizontal everywhere, which can produce a significant numerical benefit when computing the pressure-gradient force near steeply sloping terrain. The Eta Model also uses a silhouette step orography which mimics well the barrier effects of mountains on the air flow.

All Meso Eta Model runs use the same 32 km resolution version of the model with 45 levels in the vertical with the first layer over the ocean being 20 meters deep and none of the upper layers thicker than about 24 mb. The top of the model is at 25 mb. All runs are made over a large domain covering the entire North American continent. Lateral boundary conditions come from the AVN runs which are normally only 6 hours old.

Initial conditions for all four Meso Eta runs comes from the Eta Data Assimilation System (EDAS). This system also runs at 32 km resolution and cycles on itself using short 3-hour forecasts from the previous cycle as the first-guess for each analysis update. The analysis update is performed in the Eta coordinate and is based on a 3-dimensional variational (3D-VAR) scheme which uses all available data sources: radiosondes, pibals, dropsondes, profilers, VAD wind profiles from the WSR-88D network, ACARS wind and temperature data, all conventional & automated (ASOS) surface land & marine (drifting & moored buoys) reports, data from polar orbiting satellites (from DMSP: SSM/I ocean wind speeds and total precipitable water and from TOVS: oceanic thickness retrievals) and data from geostationary satellites (cloud drift winds and precipitable water retrievals). No initialization of the analysis fields is performed since the 3D-VAR produces mass and wind fields which are balanced.

At the initial time and every 3 hours of the forecast, isobaric height, wind, and temperature fields every 25 hPa, and at each of the aviation-winds-aloft altitudes are generated on standard output grids (80 km, 40 km & 20 km AWIPS grids and the NGM C-grid). Relative humidity, vertical velocity and cloud

fields, freezing levels (upper and lower), lifted indices, CAPE, CINH and helicity as well as tropopause and max wind level information are also generated. Precipitation is accumulated every 3, 6 and 12 hours throughout the forecast and are found to verify better than other NCEP model forecasts. Hourly wind, temperature and moisture soundings are provided at nearly 1200 hundred locations in the domain and are encoded into BUFR. Also included with the hourly soundings are the model cloud fields, helicity, CAPE, CINH, runoff, and precipitation type. To support the Interactive Forecast Preparation System (IFPS), fields of max and min surface temperature (2 m), surface (10 m) wind speed and direction, surface (2 m) temperature and dew point, total cloud, accumulated precipitation & snow, and probability of thunder, frozen & freezing precipitation are generated on 20 km and 40 km AWIPS grids.

3.1.1 The On-time Meso Eta Runs (ERL)

The on-time (so called “early” or ERL) runs of the 32 km / 45 level Meso Eta provide 48 hour regional forecasts over North America to the National Weather Service and the meteorological community at large as soon as possible after the 0000 and 1200 UTC synoptic times. The data cutoff time for the ERL runs is roughly 70 minutes. During the post-fire period, these runs were made at 80 km / 38 level resolution on a smaller Cray J-916 but this produced ERL guidance on schedule. These runs were moved from that Cray C-90 to the new IBM SP computer in November 1999 and returned to full 32 km / 45 level resolution.

3.1.2 The Off-time Meso Eta Runs (MSO)

The off-time runs of the 32 km / 45 level Meso Eta were originally referred to as the Mesoscale or MSO run. They also provide regional forecasts over North America to the National Weather Service and the meteorological community at large as soon as possible after 0600 and 1800 UTC. The data cutoff time for the MSO runs is roughly 35 minutes. Since November 1999, forecasts out to 48 hours are now made from both 0600 and 1800 UTC runs. Prior to their implementation on the new IBM in November 1999, the 0600 UTC run was actually a 0300 UTC run which ran to 33 hours and the 1800 UTC run was made out to only 30 hours. During the post-fire period, these runs could not be made by NCEP and replacement fields for CONUS were generated on schedule from 36 km runs of MM5 made by and kindly provided by AFWA.

3.2 The Regional (RGL) Run

The RGL run produces forecasts to 48 hours for North America, using the Regional Analysis and Forecast System (RAFS), and a data cutoff time of H+2:00. The RGL run has been "frozen" since 1991.

The RGL initial conditions are produced by the Regional Data Assimilation System (RDAS), which uses a Regional Optimum Interpolation (ROI) analysis system, and starts with a first guess based on a 6 hour forecast from the earlier GDAS run. Sequences of analyses and short range forecasts from the Nested Grid Model (NGM) are produced every 3 hours during the 12 hour pre-forecast period. The analysis grid has a resolution of approximately 85 km over North America and 170 km elsewhere. The analyses are performed on the same 16 sigma layers as used in the NGM. Forecasts during this assimilation period are made using "one-way" boundary conditions extracted from the final (FNL) global analyses and short range forecasts and are performed only on the innermost "C-grid". For the last, "on-time" analysis, the RDAS C-grid guess is merged with the corresponding FNL-run guess to provide full hemispheric fields. After this analysis is completed, the analysis increments are initialized, bringing the mass and motion fields into approximate balance.

The NGM forecasts on 16 sigma layers and a 2-grid nested system out to 48 hours. The forecast grids have approximate resolutions of 170, and 85 km at 45°N and are referred to as the "B", and "C" grid respectively. The denser grid covers all of North America and extends beyond the pole to cover much of northern Europe and Asia, while the coarse grid is hemispheric. The initial snow cover field comes from an analysis updated daily. Gridded field output is generated for pressure levels every 50 hPa at six hourly intervals on the NGM C-grid and hourly BUFR soundings are generated at selected sites as well. During the post-fire period, this system (sans RDAS) was run on a Cray J-916 - consequently, product availability was delayed by roughly an hour. A version of this system using Meso Eta 3D-VAR analyses over North America and AVN fields elsewhere is being prepared for implementation on the IBM. For details see: ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/ngmcafti/index.htm or ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/ngmtpb/ngmtpb.html.

Statistical guidance based on the MOS technique is produced twice daily from the NGM. Forecasts are disseminated in alphanumeric form for approximately 600 civilian stations and 160 military bases in the contiguous United States and Alaska. Guidance is available for max/min temperature; temperature and

dew point at the 2-m shelter height; surface wind direction and speed; probability of thunderstorms and severe thunderstorms (contiguous U.S. only); probability of precipitation (PoP); conditional probability of freezing precipitation and snow; and categorical forecasts of precipitation type, opaque cloud cover, snow amount, quantitative precipitation, ceiling height, visibility, and obstruction to vision. This package of statistical forecasts is used in the comparison to official forecasts evaluated in the national verification program (see Part VI, 5.2); most of the forecasts are also made available in gridded form to Family of Services and NWS AWIPS users. In addition, MOS solar energy and sunshine forecasts for the contiguous U.S. are disseminated in graphical form. MOS forecasts of thunderstorms for Alaska and Florida are issued in gridded form, and forecasts from the NGM-based trajectory model are issued in both alphanumeric and graphical products. MOS forecasts of non-convective clear-air turbulence and icing are issued in graphical form. Guidance for the marine environment includes wind forecasts for areas along the Great Lakes; wind forecasts for coastal areas along the Atlantic Ocean, Pacific Ocean, and the Gulf of Mexico; extratropical storm surge and beach erosion forecasts for the east coast of the U.S.; and storm surge forecasts for the Great Lakes.

3.3 The Rapid Update Cycle (RUC) Run

The new version of the RUC designated as RUC2 provides high-frequency, short-term forecasts for domestic aviation purposes on a 40-km resolution domain covering the lower 48 United States and adjacent areas of Canada, Mexico, and ocean. Every three hours or 8 times per day, the RUC2 produces an analysis and hourly forecast files out to 12 hours. Every other hour or 16 times per day, the RUC2 produces an analysis and hourly forecast files out to 3 hours. At 0000 UTC and 12000 UTC, a 58 minute data cutoff is used to allow the radiosonde data to be included. At all the other times, a cutoff of 20 minutes is used. The OI analysis relies heavily at asynoptic times on data from ACARS aircraft and wind profilers (the use of VAD winds from the WSR-88D radars had been turned off during 1999). An entire cycle consisting of an analysis and 12 hour forecast runs in about 50 minutes.

The RUC was developed by NOAA/OAR's Forecast Systems Laboratory where it is known as the Mesoscale Analysis and Prediction System (MAPS). One of its unique aspects is its use of a hybrid vertical coordinate that is primarily isentropic. Most of its 40 levels are isentropic except for layers in the lowest 1-2 km of the atmosphere where terrain-following coordinates are

used. The two types of surfaces change smoothly from one to another.

The RUC2 performs a multivariate OI height/wind analysis and subsequent univariate analyses of virtual potential temperature and condensation pressure. A 3D-VAR is being developed to replace the OI analysis. The first guess is the one hour forecast from the previous cycle. Lateral boundary conditions are specified from forecasts from the Meso Eta model.

RUC2 output is converted to standard meteorological variables and vertical coordinates for users in the Gridded Binary (GRIB) format. The RUC2's 40 km computational grid is a subset of the 40 km AWIPS Lambert conformal projection and therefore no horizontal interpolation is required. Output grids of temperature, heights, relative humidity, and u,v winds are interpolated vertically to isobaric levels between 1000 and 100 hPa every 25 hPa. During the post-fire period, only the old 60 km RUC would have been possible to run on the smaller J-916, so FSL kindly provided timely replacement grids directly to OSO from their hourly 40 km MAPS runs.

3.4 Hawaiian Islands Run

This run provides forecasts over the Hawaiian Islands at a very high resolution (10 km) from 0000 and 1200 UTC out to 48 hours for distribution to Hawaii via FTP (INTERNET). The model used in this run is the Regional Spectral Model. This model is identical to the global spectral model used in the AVN, MRF and FNL, except that it is run over a small domain at much higher resolution. Initial conditions and boundary conditions for this run are interpolated from the current AVN run. A higher resolution depiction of terrain is used but little vertical interpolation is required since the number of levels is the same as in that run (42 sigma levels). During the post-fire period, the 10 km RSM was run on the smaller J-916 and, consequently, its guidance was delayed by several hours. The RSM was moved to the IBM in early February 2000. A 10 km version of the Meso Eta Model with a mini-EDAS is being prepared as a possible replacement for the RSM system in this application.

3.5 The Aviation (AVN) Run

The AVN is run four times daily, from initial conditions at 0000, 0600, 1200, and 1800 UTC out to 84 hours. Its primary purpose is to prepare guidance in support of NCEP's international aviation responsibilities. The data cutoff time is 2:45 to speed up reception of the aviation guidance over the GTS.

The forecast model and analysis system used in the AVN run are identical to those used in the MRF, and are described below. Any differences in performance arise from the earlier cutoff time of the AVN.

The analysis method is multi-variate Spectral Statistical Interpolation (SSI). As with the other forecast runs, the six hour forecast from the Final run (4.9) is utilized as the first analysis guess. The analysis adds corrections to the first guess directly in the model variables and coordinate system.

The forecast, using an 126-wave triangular truncation and 28 vertical levels, is run to 84 hours, with the production of pressure level information at 3-hour intervals, as well as in spectral coefficient form.

Objective guidance based on the MOS approach is available for max/min temperature, PoP, mean cloudiness, and conditional probability of snow for projections of 24 to 72 hours in advance. The guidance is produced from both the 0000 and 1200 UTC runs of the AVN model and is available for more than 225 stations in the contiguous U.S., Alaska, and southern Canada. Forecasts are issued in alphanumeric messages, and are available in also gridded form. Extratropical storm surge forecasts are generated twice daily for projections out to 48 hours for numerous sites along the east coast and northwest coast of the U.S., the Gulf of Mexico, and the coast of Alaska along the Bering Sea.

3.6 The Hurricane (HCN) Run

The Hurricane (HCN) run provides numerical guidance for hurricane track and intensity forecasts made by the Tropical Prediction Center (TPC), Miami for tropical storms or hurricanes in the Atlantic, East Pacific, or Caribbean basins (including the Gulf of Mexico). The HCN run may also be initiated on request from the TPC for a tropical depression that is expected to intensify into a tropical storm or hurricane.

The HCN forecast model is the Geophysical Fluid Dynamics Laboratory (GFDL) Hurricane Model (GHM), which is a triply-nested model with resolutions of 1.0, 1/3, and 1/6 degree latitude resolution and 18 vertical levels. The outermost domain extends 75° in the meridional and longitudinal directions. Initial conditions are obtained from the current AVN run (3.5 above). Input parameters for each storm are provided by the TPC and include the latitude and longitude of the storm's center, current storm motion, the central pressure, the radii of 15 m/s

and 50 m/s winds. Output from the model consists of forecast track positions and maximum wind speeds, various horizontal fields on pressure surfaces (such as winds and sea-level pressure), and some graphics products such as a swath of maximum wind speeds and precipitation throughout the 72 hour forecast occurring at each model grid point.

3.7 The NCEP Tropical Cyclone Synthetic Data System (SDS)

The purpose of the NCEP tropical cyclone Synthetic Data System (SDS) is to produce a cyclone-like vortex correctly positioned in the global model analyses and to track this vortex throughout the model forecast.

Input data to the SDS are provided by operational tropical cyclone forecast centers around the world such as the Tropical Prediction Center, Miami. NCEP receives data on storms in the Atlantic, East and Central Pacific, West Pacific, Australian and Indian Ocean basins. The storm data consist of storm positions, current motion, and various strength and size parameters such as the central pressure.

The synthetic data are wind-only soundings derived from the tropical cyclone strength and size parameters. These soundings are added to the data base for each global model analysis. The analysis treats these soundings as input observations.

An automated vortex tracker has been added to derive storm forecast positions from the model output. The tracker scans the model wind and height fields for each forecast time to pick up a signature that is characteristic of a tropical cyclone. Tracks are produced twice daily from the Aviation model run for all storms on a global basis and once daily from the MRF run. Diagnosed tracks in the Atlantic and the East and Central Pacific are reported to the Tropical Prediction Center and are added to an on-line track archive.

3.8 The Medium-Range Forecast (MRF) Run

The MRF run produces a global forecast to day 16 at 00 UTC only. It uses a 126-wave triangularly truncated (T126) horizontal resolution for the first seven days and T62 out to day 16. Vertical resolution is 28 levels throughout. The MRF uses the same analysis as the Final run (see below). Data cutoff time is H+6:00.

Objective guidance based on the MOS approach is

available for the max/min temperature, PoP, mean cloudiness, mean wind speed, and conditional probability of snow for projections of 1 to 8 days in advance for more than 225 stations in the contiguous U.S., Alaska, and southern Canada. These forecasts are produced once a day from the MRF model and are available to NCEP to aid in the preparation of the medium-range forecasts. The medium-range guidance is also disseminated directly to NWS forecasters. Ensemble-based MOS forecasts of max/min temperature and PoP are generated for the same set of stations as included in the basic MRF MOS package. In addition, unique MOS guidance packages are produced for specialized users. Guidance for air and soil temperatures, sunshine, minimum relative humidity, and ground condensation is generated for a number of agricultural stations in South Carolina. Forecasts of max/min temperature, PoP, and QPF are disseminated for stations in Washington, Oregon, Idaho, Montana, and southwestern Canada.

3.9 The Final (FNL) Run

The FNL run, the last run in any one cycle, produces the best analysis and first-guess (6 hour forecast)four times daily for the next analysis/forecast cycle by delaying the run as long as possible to pick up late-arriving conventional and satellite data. This analysis/forecast procedure is known as the Global Data Assimilation system (GDAS). Data cutoff times are H+6:00 for the 0000 GMT run; H+9:30 for the 0600 GMT run; H+9:00 for the 1200 GMT run; and H+9:30 for the 1800 GMT run.

The conventional and satellite data are analyzed with the Spectral Statistical Interpolation (SSI) analysis system. Since October 1995 satellite radiances from polar-orbiting satellites were used rather than satellite retrievals in the analysis. In 1998, GOES radiances were included. In early 1999 AMSU/A radiances were added.

3.10 The Ensemble Run

During the past year the global operational ensemble system was configured to have 17 forecasts per day. The ensemble mean forecast often has useful skill on a daily basis out to 16 days lead time during the winter half year. Considerable effort has been put into displaying user friendly information from the ensemble for use of NCEP and outside forecasters. Both the original forecast data and the postprocessed probability information in graphics format have been made available through an anonymous ftp account to the general user community.

3.11 Wave Forecast Run

The NOAA WaveWatch3 (NWW3) has been accepted for implementation to produce global wave forecasts on the Class VIII computer. The global model has a 1x1.25 degree spacial resolution in latitude/longitude and has 25 frequencies and 24 directional bands. This model will replace the WAM-Cycle4 which is being used for operational wave forecasts until now.

4. PLANS FOR FUTURE OPERATIONAL SYSTEMS

4.1 Regional/Mesoscale Guidance

4.1.1 Eta Changes

4.1.1.1 March 2000 Changes

(1) Change the convection scheme to increase likelihood of convection over higher terrain and to reduce the high coastal bias in southeast.
(2) Extend the on-time runs to 60 h.
(3) Provide AWIPS SBN with higher resolution grids (40 km grid #212 and 20 km grid #215) from the on-time runs.
(4) Account for the drift of the radiosonde balloon in the 3D-VAR analyses.
(5) The WSR-88D VAD winds will be turned back on and incorporated into the 3D-VAR with a new QC package.
(6) The Shuell pressure reduction will be added as an alternative sea-level pressure field.
(7) Bunkers dynamic method will be used to compute (supercell) storm motion.

4.1.1.2 May/June 2000 Changes

An extension of the 0000 UTC run out to 84 hours and extension of the 1200 UTC run to 72 hours is planned for an internal implementation. Product distribution will initially be via ftp.

4.1.1.3 August 2000 Changes

(1) Implement new 3D-VAR analysis code which will use the Message Passing Interface (MPI) paradigm to make use of multiple nodes on the IBM computer.
(2) Direct 3D-VAR analysis of radiances from polar-orbiting and geostationary satellites
(3) EDAS assimilation of observed precipitation and cloud top pressure.
(4) Analysis of radial velocity from WSR-88D radar.
(5) Increase analysis update frequency in the EDAS from every 3 hours to every hour.
(6) Increase horizontal resolution from 32 km to 22 km with expansion of domain (to the west) back to pre-32km size.
(7) Increase number of vertical levels from 45 to 50.

(8) Improve model physics: land-surface package upgrade to version 2.0, convection & grid-scale precipitation, diffusion etc.

4.1.1.4 Longer Term Changes

Current thinking and published NWS commitments call for a high resolution 10-12km/ 70 level Meso system (forecast model and 3DVAR/EDAS) to be ready for acceptance testing and benchmarking on the Phase II IBM. This represents a substantial acceleration of current efforts. Current NWS and NCEP requirements call for 84-hour forecasts from 00 UTC, 72-hour forecasts from 1200 UTC, and 54-hour forecasts from 0600 and 1800 UTC.

4.1.1.5 Salt Lake City Olympics Support

A high resolution Eta-10 will be running out to 60 hours from November 2000 to March 2001 at least twice per day, and depending on computer availability, four times per day. This would keep the model and output as nearly identical as possible between the two years and would allow NCEP to make the Eta-10 operational in November 2001 (as planned & promised) while giving the special weather support team this guidance during the previous winter. The workstation version of the Eta is also available to be run on a scheduled or on-demand basis to provide additional support.

4.1.2 NGM March 2000 Changes

The NGM will be initialized using the “early” Eta 3D-VAR over North America and the AVN over the remainder of the grid. Warm and cool season tests have been made with only slight degradation (largely due to earlier data cutoff). Implementation on the IBM is tentatively scheduled for 15 March 2000. NGM and NGM MOS guidance will then be available roughly 50 minutes sooner.

4.1.3 Saudi Eta Changes

It is anticipated that more work will be done using higher resolution (~22 km grid spacing) Eta runs covering smaller domains, particularly during the summer season when synoptic-scale influences are weaker. How well the Eta model represents the observed sea-breeze circulation will be of interest, as will its treatment of convection over the mountainous southwestern part of the Kingdom. The experimental nonhydrostatic model of Janjic will also be applied to these problems.

4.1.4 Weather Research and Forecasting (WRF) Model Development

NCEP has joined forces with NCAR, FSL, and CAPS to begin a co-development of a next generation storm-scale mesoscale modeling system. The co-development provides an opportunity to combine the expertise of operational and research modelers in collaborative development of an improved mesoscale weather forecast modeling and data assimilation system. In developing this model, there will be an objective evaluation of alternative approaches so that the best features of existing mesoscale models can be used and new techniques can be developed where deficiencies are identified. The NCEP contribution to the WRF will be a nonhydrostatic model using semi-Lagrangian numerical techniques and will be designed for 1-10 km horizontal resolution with advanced data assimilation and physics. It will be accurate and efficient across a broad range of scales and will be well suited for both research and operations. For more information on the WRF Model see: http://www.emc.ncep.noaa.gov/mmb/wrf/index.html and http://box.mmm.ucar.edu/wrf/ .

4.1.5 Short-Range Ensemble Forecasting

Commence routine production of the SREF system and product suite (SREF-I) on IBM SP by April 2000. Systematic evaluation then follow. The target system will be a 10 member, 48 km North American domain running twice a day to 60 hours with output available every 3 hours. The initial perturbations will be regionally bred. The initial SREF-I has no perturbations on model physics. The output will include ensemble mean and spread charts, spaghetti charts, probability charts, and meteograms.

4.2 Global Guidance

Extend the AVN forecasts to 126 hours for 00 GMT and 12 GMT to provide guidance and boundary forcing for Hurricane forecast models.

Test higher vertical resolution version of the model (42 levels to 60 levels) to make better use of satellite radiance observations.

Modify convection and tropical storm initialization procedures to reduce false alarms and to improve guidance for tropical storms.

Test and implement prognostic condensate scheme.

Implement improved ozone error covariance estimates.

Test and include new observations such as GOES-10 sounder and Quickscat.

Test and implement a new quality control procedure for radiosondes.

4.3 Marine Prediction

High resolution SSM/I retrievals from the OMBNN# neural network algorithm will be tested and implemented in the data assimilation cycle of the Eta models.

NCEP's new third generation global wave forecast model and the regional models for the North west Atlantic and the Alaskan Waters regions will be implemented on the IBM

The Coastal Ocean forecast System will be run in an experimental mode to provide guidance to a selected set of users during the second Coastal Marine Demonstration Project in February-March, 2000. A final summary of the two CMDP efforts will be prepared.

A development of sea ice climatology to provide daily and monthly normals will be initiated for use in developing statistical forecasts.

4.4 Hurricane Prediction

Coupled atmosphere-ocean forecasts using the GFDL hurricane model and the Princeton ocean model will be tested during the summer of 2000. The development was done by Isaac Ginis of the University of Rhode Island.

4.5 Statistical Guidance

Efforts to develop and implement the MOS-2000 system will continue. A complete MOS forecast system based on the AVN run of the Global Spectral Model will be implemented. The MRF-based MOS system will be enhanced by adding forecasts for additional weather elements and sites. Thunderstorm and precipitation amount guidance based on the Eta model will be developed and implemented. Statistical methods will be improved through use of new techniques. Objective guidance products will be enhanced by extending forecast areas, including more localities, and adding new weather elements and forecast projections.

A new version of the three-dimensional trajectory model will be implemented to run from wind forecasts generated by NCEP's Eta model. The Eta-based trajectory model will serve as a replacement for the NGM-based version when the NGM is discontinued

Development and testing of the 0-3 h QPF algorithm will continue. Operational production and dissemination of a national-scale radar mosaic will begin. The mosaic will serve as input to various AWIPS applications. A second operational version of SCAN, which includes key functionality of NSSL's Warning Decision Support System as well as automated threat indices for severe weather and flash floods, will be developed.

The LAMP cloud layer algorithm will be implemented within the AWIPS environment. Techniques for producing LAMP forecasts from any initial hour will be tested and implemented. Work will continue on the preparation of site-specific equations, thresholds, weight files, and location files for individual WFO's for implementation within AWIPS. In addition, the LAMP guidance will be verified. The LAMP QPF model will be implemented at local NWS offices within AWIPS during the next year. An effort will also be made to improve the model's 1- and 3- h analyses of antecedent precipitation.

The hurricane storm surge model, SLOSH, will be applied to other hurricane-prone areas. Changes in physical features will be incorporated into the model, as will changes initiated by improved mapping of coastal areas. Forecasting of storm surge caused by extratropical cyclones will be improved, and new products from the extratropical storm surge model will be available for coastal areas of the U.S. Inclusion of wave effects into surge models will lead to better forecasts of water levels at the coastline.

Interactive model interpretation and graphical forecast editing will be the focus of evaluation at new IFPS rapid prototype sites next year. One site in each NWS region has been selected to experiment with producing new grid-based forecast products via IFPS. Rapid prototyping will be done in parallel with national training and deployment of baseline IFPS capabilities.

5.1 Verification Against Analyses

Precipitation continued to be the output field to which a high priority was accorded in monitoring the performance of the Eta Model. Relative performance in terms of precipitation scores against other NCEP operational models continued to be monitored as well. This verification is based on EMC's precipitation analysis system, which uses data provided by the NWS's River Forecast Centers (RFCs). They consist of reports of accumulated precipitation for each 24-h period ending at 1200 UTC. The analysis covers the area of the contiguous United States with reports from on the order of ten thousand rain gauge stations. In areas of poor coverage, RFCs data are augmented by radar precipitation estimates if rain gauge data are available in the vicinity to calibrate the radar data. Data are analyzed to verification grid-boxes by simple box averaging. Grid boxes which contain no reports or calibrated radar data are not included in the verification.

Equitable precipitation threat and bias scores for 1999 and for three NCEP/EMC operational models, Eta (32 km/45 layer during 1999), the Aviation (AVN)/Medium Range Forecasting (MRF) Model, and the NGM, are shown in Fig. 1. The figure caption contains definitions of the two scores. The AVN/MRF model is verified on its grid; the Eta and the NGM forecasts are remapped to an 80-km grid for verification. Partly for inadvertent reasons, the verification system has changed in 1999 compared to the one used to produce plots of the reports of the two preceding years. One change is that, starting with April, for both the 0000 and 1200 UTC the AVN run is verified. Another is that the NGM forecasts are remapped; this is believed to have had little impact since the NGM and the 80-km verification grid are of very similar sizes. Yet another change is that, as of April, the 3 inches/24 h and greater category has been included in the system so that now nine categories are monitored.

In view of the significant year-to-year variability of precipitation scores as a result of climate variations alone, a relative comparison of models may be of just as much interest as the actual scores. In this sense, compared to the scores of 1998, the Eta as well as the AVN/MRF Model are seen to have increased their advantage over the NGM at the two least intense precipitation categories; and to have demonstrated less of an advantage at the remaining categories up to and including 2 inches/24 h. Since the NGM system is frozen, reasons for this are not obvious and are suspected to be in climate variations as well. The relative standing of the two "live" models, the Eta and the AVN/MRF, is similar to that of the preceding year.

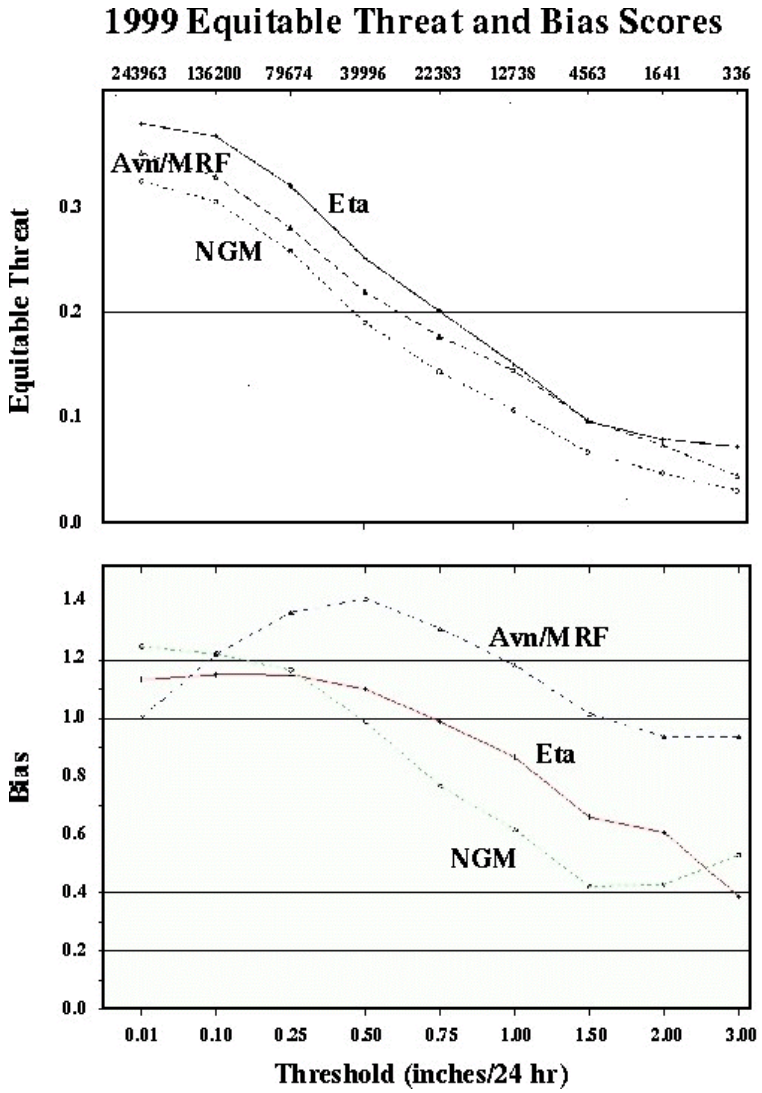

Fig. 1. Equitable precipitation threat scores (upper panel) and bias sores (lower panel) for 1999, for the Eta Model for the Aviation/MRF Model (AVN/MRF) and the NGM.

The equitable threat score is equal to (H-E)/(F+O-H-E) , where H is the number of "hits", E=FO/N is the number of hits in a random forecast, F is the number of forecast points, O is the number of "observed" points, and N is the total number of points verified. The bias score is equal to F/O. The numbers below the abscissa of the lower plot show the precipitation thresholds, in inches/24 h, which are verified. The numbers above the upper plot show the total number of the 80-km verification boxes which were "observed". Scores are for a sample containing three verification periods, 0-24, 12-36, and 24-48 h, of all the forecasts that were recorded by the system. The skill at 3 inches and greater may be of special interest as this category is a new feature and

as it illustrates the model performance in very heavy precipitation events such as hurricanes and other major rainstorms. Six events have been noted responsible for positive skill at that category, including an orographic rain event over the Pacific Northwest, two lows over the Gulf coastal regions, Hurricane Irene, Hurricane Dennis, and a frontal event with very heavy rains stretching across central Maine south-southwestward towards and into eastern Connecticut. The rain from the most intense landfalling hurricane of the season, Floyd, failed to be included due to technical problems. The large advantage of the Eta at 3 inches and greater is for the most part due to its skill in the New England event, on 11 September, with the model forecasting correctly about two thirds of the eight "observed" verification boxes, in each of its three consecutive "on time" (0000 and 1200 UTC) forecasts.

5.2 MOS Products

A national verification program, designed to verify local official forecasts and to compare their skill and/or accuracy to MOS guidance, has been in operation for over 25 years. Forecasts included in the comparison are: probability of precipitation, max/min temperature, surface wind, cloud amount, ceiling height, visibility, snow amount, and precipitation type. While considerable variation exists in the relative accuracy of guidance and local forecasts for different elements, verification scores clearly indicate the usefulness of the MOS guidance.

A quantitative illustration of the PoP guidance performance is given in Fig. 2 which shows the overall skill in terms of percent improvement over climate of the PoPs during the cool (October-March) and warm (April-September) seasons for the period from April 1972 through September 1999. During this period, the guidance was produced exclusively by the MOS approach. The comparison is made in terms of a score P, defined for a sample of size N as follows:

$$P = \frac{1}{N} \sum_{i=1}^{N} (f_i - E_i)^2,$$

where f_i is the forecast probability that precipitation will occur for the i-th case, and E_i equals the value of 1 or 0, respectively, according to whether precipitation did or did not occur. The results indicate that the percent improvement in P-score over climate for the PoP guidance increased over the years as changes were made to the MOS system and the underlying dynamical model.

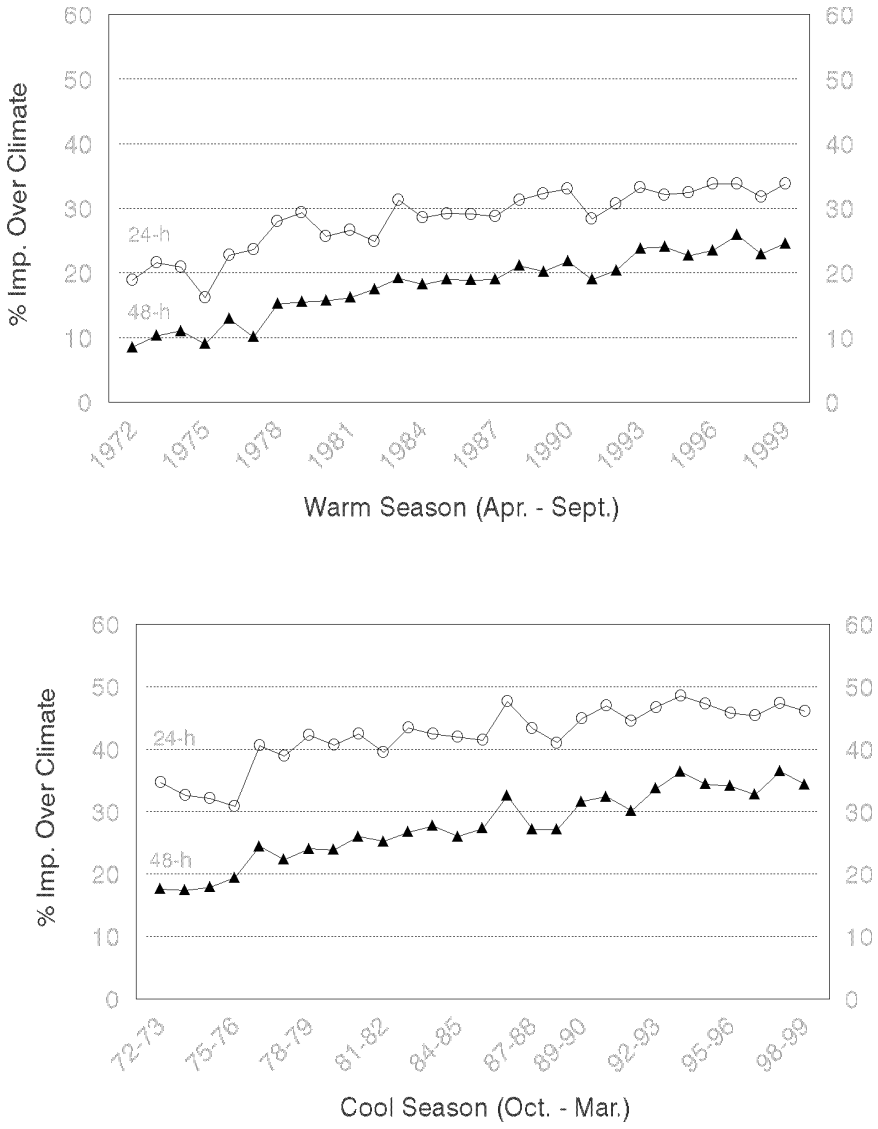

Figure 2. Percent improvement over climate in the P-score for the probability of precipitation guidance. The forecasts were based on 0000 and 1200 UTC cycle data for approximately 80 stations in the contiguous United States prior to October 1983 and for approximately 90 stations after that time. Cool season results for the 1996-1997 season were only available for the October through December period.

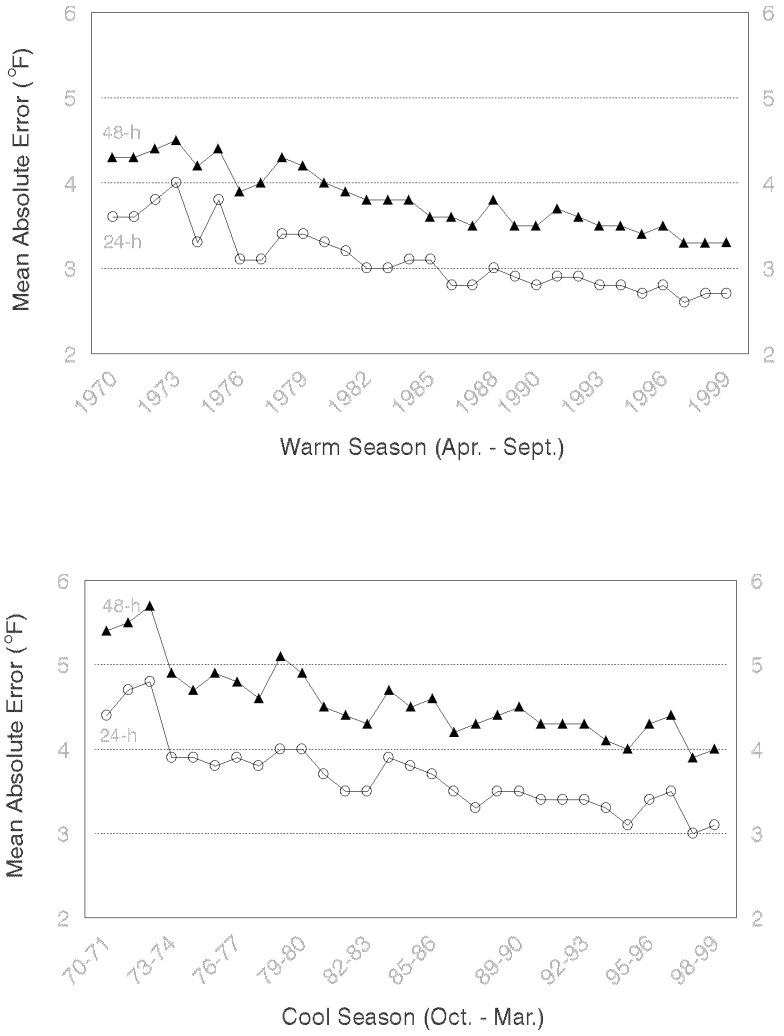

Figure 3. Mean absolute error (°F) of the 24- and 48-h max temperature guidance. The forecasts were based on 0000 UTC cycle data for approximately 80 stations in the contiguous United States prior to October 1983 and for approximately 90 stations after that time. Cool season results for the 1996-1997 season were only available for the October through December period.

Similarly, Figs. 3 and 4 show mean absolute errors for the objective max and min temperature forecasts, respectively, during the period from April 1970 through September 1999. From April 1970 until August 1973, the objective guidance was based on the perfect prog method. From August 1973 to the present, the guidance was produced exclusively by the MOS approach. Note the substantial improvement in both the max and min temperature

guidance since 1970. In fact, the mean absolute errors for the 48-h max forecasts during the cool season are now about the same as the errors for the 24-h guidance of 15 to 20 years ago. A large portion of the apparent improvement in the min temperature guidance occurred in November 1985 when the guidance was modified to predict a nighttime min instead of a calendar day min. Prior to that time, the guidance was valid for a calendar day min, but was verified by using an observation of the nighttime min. With

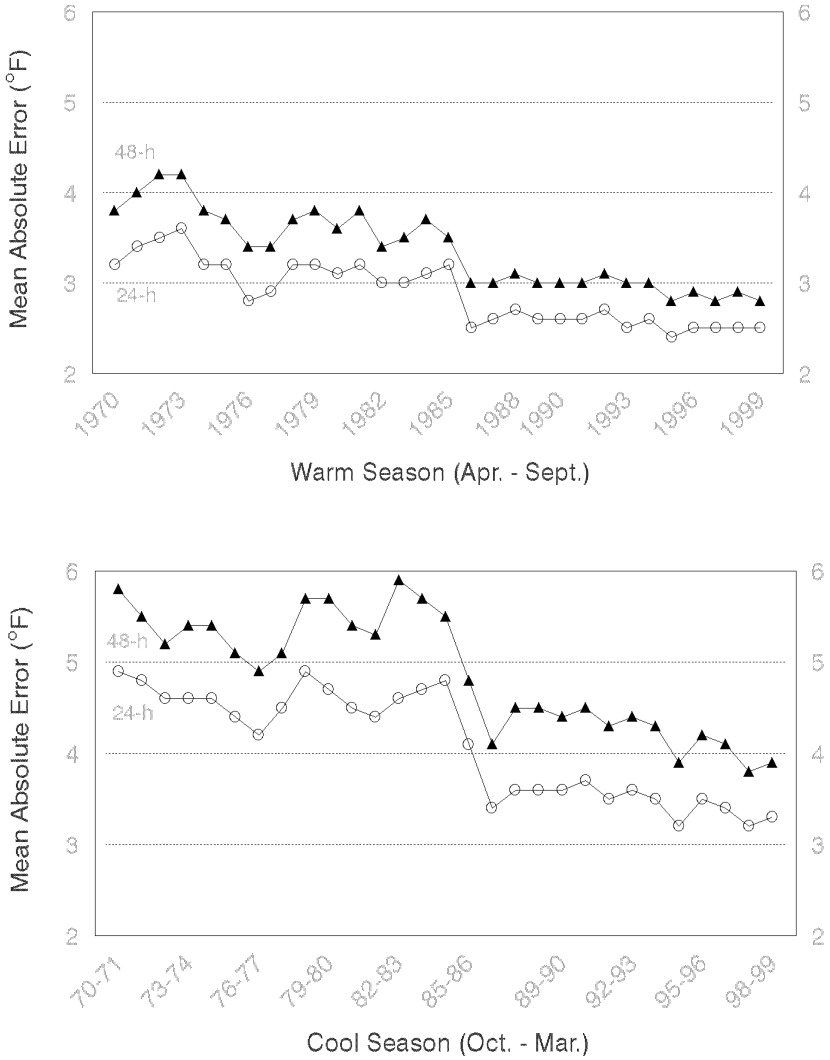

Figure 4. Mean absolute error (°F) of the 24- and 48-h min temperature guidance. The forecasts were based on 0000 UTC cycle data for approximately 80 stations in the contiguous United States prior to October 1983 and for approximately 90 stations after that time. Cool season results for the 1996-1997 season were only available for the October through December period.

the November 1985 implementation, the valid period of the guidance and the verifying observation matched.

6. PUBLICATIONS

NCEP

Angevine, W., and K. Mitchell, 1999: Model comparisons with turbulent measurements from wind profilers. *Preprints, 13th Symposium on Boundary Layers and Turbulence*, Dallas, Texas, Amer. Meteor. Soc.

Barsugli, J. J., J. S. Whitaker, A. F. Loughe, P. Sardeshmukh, and Z. Toth, 1999: Effect of the 1997-98 El Nino on individual large-scale weather events. *Bull. Amer. Meteor. Soc.*, *80*, 1399-1411.

Berbery, E., K. Mitchell, S. Benjamin, T. Smirnova, H. Ritchie, R. Hogue, and E. Radeva, 1999: Assessment of land-surface energy budgets from regional and global models. *J. Geophys. Res.*, *104*, 19329-19348.

Bishop, C. H., and Z. Toth, 1999: Ensemble transformation and adaptive observations. *J. Atmos. Sci.*, *56*, 1748-1756.

Chalikov, D., L. C. Breaker, V. Krasnopolsky, and D. B. Rao, 1999: Revisiting the Question of Assimilating Temperature alone into a Full Equation of State Ocean Model, *Ocean Modeling*, *116*, 13-14.

Chen, F., and K. Mitchell, 1999: Using the GEWEX/ISLSCP forcing data to simulate global soil moisture fields and hydrological cycle for 1987-1988. *J. Meteor. Soc. of Japan*, *77*, 167-182.

Chen, H. S., 1999: Prediction of Ocean Wind Waves. *Proceedings of The 1999 CAAPCON Convention*, Washington, DC, July 1999, 6.17.1-6.17.4.

Derber, J., and F. Bouttier, 1999: A reformulation of the background error covariance in the ECMWF global data assimilation system. *Tellus*, *51A*, 195-221.

Gemmill, W. H., and V. M. Krasnopolsky, 1999: The use of SSM/I data in operational marine analysis. *Weather and Forecasting*, *14*, October 1999, 789-800.

Hong, S.-Y., H.-M. H. Juang, and D.-K. Lee, 1999: Evaluation of a Regional Spectral Model for the East Asian monsoon case studies for July 1987 and 1988. *J. Meteor. Soc. of Japan*, *77*, 553-572.

____, and A. Leetmaa, 1999: An evaluation of the NCEP RSM for

regional climate modeling. *J. Climate*, *12*, 592-609.

Koren, V., Q. Duan, J. Schaake, and K. Mitchell, 1999: Validation of the snow-frozen ground parameterization of the Eta Model. *Preprints 14th Conference on Hydrology*, Dallas, Texas, Amer. Meteor. Soc.

_____, J. Schaake, K. Mitchell, Q. Duan, F. Chen, and J. Baker, 1999: A parameterization of snowpack and frozen ground intended for NCEP weather and climate models. *J. Geophys. Res.*, *104*, 19569-19585.

Krasnopolsky, V. M., 1999: Using NNs to retrieve multiple geophysical parameters from satellite data. *Proceedings of 1999 International Joint Conference on Neural Network*, July 10-16, 1999, Washington, DC, 198-204.

_____, W. H. Gemmill, and L. C. Breaker, 1999: A multi-parameter empirical ocean algorithm for SSM/I retrievals. *Canadian Journal of Remote Sensing*, *25*, December 1999, 486-503.

Kumar, A., and M. P. Hoerling, 1999: Analysis of atmospheric response to tropical Pacific SST's in different AGCMs. *Preprints 8th Conference on Climate Variations*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Langland, R., Z. Toth, R. Gelaro, I. Szunyogh, MK. Shapiro, S. Majumdar, R. Morss, G. D. Rohaly, C. Beiden, N. Bond, and C. Bishop, 1999: The North Pacific experiment (NORPEX-98): Targeted observations for improved north American weather forecasts. *Bull. Amer. Meteor. Soc.*, *80*, 1363-1384.

Levy G., and T.-W. Yu, 1999: A diagnostic study of surface dynamics of oceanic storms. *Preprints 17th Conference on Weather Analysis and Forecasting,* September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Lin, Y., K. Mitchell, M. Baldwin, E. Rogers, and G. DiMego, 1999: Test assimilation of the real-time, multi-sensor hourly precipitation analysis into the NCEP Eta model. *Preprints 8th Conference on Mesoscale Processes*, Boulder, Colorado, Amer. Meteor. Soc.

Marshall, C., K. Crawford, K. Mitchell, D. Stensrud, and F. Carr, 1999: Evaluation of the new land-surface and planetary boundary layer parameterization schemes in the NCEP mesoscale Eta model using Oklahoma Mesonet observations. *Preprint 14th Conference on Hydrology*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

Masutani, M., K. Campana, and S. Lord, 1999: The observing system simulation experiments for NPOESS. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc, 28-31.

_____, J. C. Woollen, J. C. Derber, S. J. Lord, J. Terry, R. Atlas, S. A. Wood, S. Greco, G. D. Emmitt, T. J. Kleespies, 1999: Observing system simulation experiments for NPOESS. *Preprint 13th Conference on Numerical Weather Prediction*, September 1999, Denver, Colorado, Amer. Meteor. Soc., 1-6.

_____, and A. Leetmaa, 1999: Dynamical mechanisms of the 1995 California floods. *J. Climate*, *12*, 3220-2336.

Mathur, M. B., K. F. Brill, and C. J. Seman, 1999: Evolution of slantwise vertical motions in NCEPs Mesoscale Eta Model. *Mon. Wea. Rev.*, *127*, 5-24.

Michalakes, J. G., R. J. Purser, and R. Swinbank, 1999: Data structure and parallel decomposition considerations on a Fibonacci acid. *Preprint 13th Conference on Numerical Weather Prediction, September 13-17, 1999,* Denver, Colorado, Amer. Meteor. Soc., 129i-130.

Mitchell, K., and J. Schaake, 1999: Recent GCIP-sponsored advancements in coupled land-surface modeling and data assimilation in the NCEP mesoscale Eta model. International Association of Meteorology and Atmospheric Sciences - International Association of Hydrological Sciences (IAMAS-IAHS) Inter-Association Symposium on Water Fluxes and Water Availability Over Continental Regions - Large Scale Budgets and Fluxes. Abstracts, p. B35, International Union of Geodesy and Geophysics (IUGG) 22nd General Assembly, July 19-30, 1999, Birmingham, England.

_____, _____, D. Tarpley, F. Chen, Y. Lin, M. Baldwin, R. Rogers, G. Manikin, A. Betts, Z. Janjic, Q. Duan, and V. Koren, 1999: Recent GCIP advancements in coupled land-surface modeling and data assimilation in the NCEP mesoscale Eta model. *Preprint 14th Conference on Hydrology*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

Pu, Z-X., S. J. Lord, and E. Kalnay, 1999: Forecast error sensitivity and adaptive observations with the quasi-inverse linear and adjoint NCEP global models. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

Purser, R. J., 1999: Legendre-transformable semi-geostrophic theories. *Jour. Atmos. Sci.*, *56*, 2522-2535.

_____, 1999: Non-standard grids. 1998 ECMWF Annual Seminar, "Recent Developments in Numerical Methods for Atmospheric Modeling", 44-72.

_____, 1999: Efficient high-order semi-Lagrangian methods. 1998 ECMWF Annual Seminar, "Recent Developments in Numerical Methods for Atmospheric Modeling", 73-94.

_____, M. Iredell, and S. Moorthi, 1999: A high-order accurate semi-Lagrangian forecast model employing a hybrid vertical coordinate. *Preprints 13th Conference on Numerical Weather Prediction*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc., 77-78.

Ralph, F. M., O. Persson, D. Reynolds, W. Nuss, D. Miller, J. Schmidt, D. Jorgensen, J. Wilczak, P. Neiman, J.-W. Bao, D. Kingsmill, Z. Toth, C. Veldon, A. White, C. King, and J. Wurman, 1999: The California land falling jets experiment (CALJET): Objectives and design of a coastal atmosphere-ocean observing system deployed during a strong El Niño. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc., 78-81.

Reynolds, R. W., 1999: Differences in sea surface temperature analyses produced by different methods - implications for climate studies. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

Stensrud, D., G. Manikin, E. Rogers, and K. Mitchell, 1999: Importance of cold pools to NCEP Mesoscale Eta Model Forecasts. *Wea. Forecasting*, *14*, 650-670.

Swinbank, R., and R. J. Purser, 1999: Fibonacci grids. September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc., 125-128.

Szunyogh, I., Z. Toth, S. Majumdar. R. Morss, C. Bishop, and S. Lord, 1999: Ensemble-based targeted observations during NORPEX. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

_____, Z. Toth, A. Emanuel, C. Bishop, C. Snyder, R. Morss, J. Woolen, and T. Marchok, 1999: Ensemble, based targeting experiments during FASTEX: The impact of dropsonde data from the LEAR jet. *QJRMS*, *125*, 3189-3218.

_____, ____, R. Wobus, and Y. Zhu, 1999: The impact of model resolution on the performance of the NCEP global ensemble forecast system. *Preprints 13th Conference on Numerical Weather Prediction*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc., 202-203.

Takle, E. S., and S.-Y. Hong, 1999: Project to intercompare regional climate simulations (PIRCS): Description and initial results. *Journal of Geophysical Research*, *104*, 19443-19461.

_____, ____, R. Wobus, and Y. Zhu, 1999: The impact of model resolution on the performance of the NCEP Global Ensemble Forecast System. *Preprints 13th Conference on Numerical Weather Prediction*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Toth, Z, I. Szunyogh, S. Majumdar, R. Morss, B. Etherton, C. Bishop, and S. Lord, 1999: The 1999 winter storm reconnaissance program. *Preprints 13th Conference on Numerical Weather Prediction,* September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

____, _____, E. Kalnay, and G. Iyengar, 1999: Comments on: "Notes on the appropriateness of 'bred modes' for generating initial perturbations." *Tellus*, *51A*, 442-449.

White, G., 1999: Systematic errors in the NCEP Operational Global Analysis/Forecast System. *Preprints 13th Conference on Numerical Weather Prediction*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Wobus, R., Z. Toth, and Y. Zhu, 1999: An evaluation of probabilistic forecasts based on the NCEP global ensemble. *Preprints 17th Conference on Weather Analysis and Forecasting*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Wu, W.-S., R. J. Purser, and D. F. Parrish, 1999: Application of spatial recursive filters to global variational analysis. *Preprints 13th Conference on Numerical Weather Prediction*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc., 44-45.

__, _____, and _____, 1999: Applications of spatial recursive filters to global variational analysis. *Preprint 3rd WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography*, Quebec City, Canada, 4pp.

Yu, T.-W., 1999: Assimilating satellite observations of ocean

surface winds in the NCEP global and regional atmospheric analysis systems. *3rd WMO Symposium on Assimilations of Observations in Meteorology and Oceanography*, Quebec City, Canada, June 7-11, 1999.

Zhu, Y., E. Rogers, P. Shafran, and S. J. Lord, 1999: NAOS experiments on the U. S. upper air observing system using NCEP global and regional forecast system. *Preprint 3rd Symposium on Integrated Observing Systems*, January 10-15, 1999, Dallas, Texas, Amer. Meteor. Soc.

___, and Z. Toth, 1999: Objective evaluation of QPF forecasts based on the NCEP ensemble. *Preprints 3rd Third International Scientific Conference on the Global Energy and Water Cycle*, Beijing, China, June 1999.

___, and ____, 1999: Calibration of probabilistic quantitative precipitation forecasts. *Preprints 17th Conference on Weather Analysis and Forecasting*, September 13-17, 1999, Denver, Colorado, Amer. Meteor. Soc.

Zupanski, D., M. Zupanski, D. F. Parrish, E. Rogers, and G. J. DiMego, 1999: Fully non-linear 4dvar data assimilation using a coarse grid resolution approximation. *Geophysical Research Abstracts*, European Geophysical Society, 24th General Assembly, Vol. 1, No. 2, 425-425.

_____, M., D. Zupanski, E. Rogers, D. F. Parrish, and G. J. DiMego, 1999: The NCEP's new regional 4D-VAR data assimilation system. *3rd WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography*, Quebec City, Canada, June 7-11, 1999, 7-7.

TDL

Battel, G. F., J. P. Tuell, G. Trojan, S. V. Romano, and B. N. Baxter, 1999: Generating automated weather summaries in the AWIPS era. *Preprints 15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., 345-348.

Charba, J. P., 1998: The LAMP QPF products. Part I: Model development. *Wea. Forecasting*, 934-965.

Erickson, M. C., 1999: Updated MRF-based MOS guidance: Another step in the evolution of objective medium-range forecasts. *Preprints 17th Conference on Weather Analysis and Forecasting*,

Denver, Amer. Meteor. Soc., 190-195.

Hirschberg, P.A., S. B. Smith, and M. M. Mercer, 2000: National Weather Service SAFESEAS - Update on a new marine/coastal monitoring and forecasting capability for AWIPS. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 128-131.

Houston, S. H., W. A. Shaffer, M. D. Powell, and J. Chen, 1999: Comparisons of HRD and SLOSH surface wind fields in hurricanes: Implications for storm surge forecasting. *Wea. Forecasting*, *14*, 671-686.

Hughes, K. K., 1999: AVN-based statistical forecasts of thunderstorms and severe thunderstorms for the contiguous U.S. *Preprints 17th Conference on Weather Analysis and Forecasting*, Denver, Amer. Meteor. Soc., 201-205.

Kim, S.-C. and J. Chen, 1999: Bottom stress of wind-driven currents over an inner shelf determined from a depth-integrated storm surge model. *J. Coastal Res.*, 766-773.

Kitzmiller, D. H., M. A. R. Lilly, and S. D. Vibert, 1999: Probabilistic 0-3 hour rainfall forecasts from an extrapolative-statistical technique utilizing radar, satellite, and lightning observations. *Preprints 29th Conference on Radar Meteorology*, Montreal, Amer. Meteor. Soc., 876-879.

Laybe, P., K. S. Sperow, and R. K. Meiggs, 2000: Generating watches, warnings, and advisory broadcast scripts for the NOAA Weather Radio using Interactive Forecast Preparation. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 90-93.

Lenning, E., and M.S. Antolik, 1999: New AVN-based MOS precipitation forecasts: Taking the primary statistical precipitation guidance to the threshold of the medium range. *Preprints 17th Conference on Weather Analysis and Forecasting*, Denver, Amer. Meteor. Soc., 196-200.

Morris, K. R., and C. K. Kluepfel, 1999: WFO forecast verification in AWIPS--initial capabilities and future plans. *Preprints 15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., 360-363.

Peroutka, M. R., and J. E. Calkins, 2000: Generating marine forecasts using Interactive Forecast Preparation. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 98-101.

Ruth, D. P., 2000: Models, forecasters, and Interactive Forecast Preparation in the new millennium. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 82-85.

Schattel, J. L., Jr., and R. K. Meiggs, 2000: Managing product improvement in the Interactive Forecast Preparation System. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 94-97.

Shirey, M. A., and M. C. Erickson, 1999: Statistical quantitative precipitation forecasts based on the medium range forecast model. *Preprints 17th Conference on Weather Analysis and Forecasting*, Denver, Amer. Meteor. Soc., 206-211.

Smith, S. B., S. K. Goel, M. T. Filiaggi, M. Churma, and L. Xin, 1999: Overview and status of the AWIPS System for Convection Analysis and Nowcasting (SCAN). *Preprints 15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., 326-329.

_____, J. Roe, M. T. Filiaggi, M. Glaudemans, M. Churma, L. Xin, and R. Erb, 2000: Flash flood monitoring and prediction in AWIPS build 5 and beyond. *Preprints 15th Conference on Hydrology*, Long Beach, Amer. Meteor. Soc..

Smith, S. B., P. A. Hirschberg, and M. M. Mercer, 1999: National Weather Service SAFESEAS - A new marine/coastal monitoring and forecasting capability for AWIPS. *Preprints 3rd Conference on Coastal Atmospheric and Oceanic Prediction and Processes*, New Orleans, Amer. Meteor. Soc., 176-179.

Sperow, K. S., R. K. Meiggs, W. J. Goodman, and W. D. Jiang, 2000: Generating watches, warnings, and advisories using Interactive Forecast Preparation. *Preprints 16th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Long Beach, Amer. Meteor. Soc., 86-89.

Tuell, J. P., B. N. Baxter, and G. F. Battel, 1999: Generating automated climatological summaries in the AWIPS era. *Preprints 15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., 349-355.

NOAA Technical Report NWS/NCEP

99-01 "Documentation of Version 2 of Relaxed Arakawa-Schubert Cumulus Parameterization with Convective Downdrafts" (Moorthi, Suarez [NASA])

NCEP OFFICE NOTES

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425 "Monitoring OF Radiosonde Heights and Temperatures by the Complex Quality Control for the NCEP/NASA Reanalysis" (Collins)

426 "The Inclusion of GPS Limb Sounding Data Into NCEP's Global Data Assimilation System" (Matsumura, Derber, Yoe [NESDIS], Vandenberghe [NCAR], Zou [FSU])

427 "Note of Cloud Cover of the ECMWF Nature Run Used for OSSE/NPOESS Project" (Masutani, Campana, Lord, Yang [CPC])

428 "Impact of the Subgrid Representation of Parameterized Convection on Simulated Climatology" (Hong)

TDL EXTENDED ABSTRACTS

Allen, R. L., 1999: AVN-based MOS precipitation type forecasts. *Program National Weather Association Twenty Fourth Annual Meeting*, Biloxi, National Weather Association, p. 36.

Carroll, K. L., and M. C. Erickson, 1999: Statistical forecasts of temperature in the medium range. *Program National Weather Association Twenty Fourth Annual Meeting*, Biloxi, National Weather Association, p. 32.

Dallavalle, J. P., and M. C. Erickson, 1999: MOS-2000: A new era in interpretive weather guidance? *Program National Weather Association Twenty Fourth Annual Meeting*, Biloxi, National Weather Association, p. 25.

Weiss, M., and J. P. Dallavalle, 1999: AVN-based statistical

forecasts of total cloud amount and ceiling height. *Program National Weather Association Twenty Fourth Annual Meeting*, Biloxi, National Weather Association, p. 41.

Smith, S. B., P. A. Hirschberg, and J. L. Partain, 1999: NWS SAFESEAS - A new marine/coastal monitoring and forecasting capability for AWIPS. *Program National Weather Association Twenty Fourth Annual Meeting*, Biloxi, National Weather Association, p. 23.

Technical Procedures Bulletin

453 "Ocean Surface Waves"
(Chen, Burroughs, Tolman)

456 "Wave Forecasting for Alaskan Waters"
(Chao, Burroughs, Tolman)

459 "Wave Forecasting for the Western North Atlantic Ocean and Adjacent Waters"
(Chao, Burroughs, Tolman)

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164 "NCEP Experience with "Real-Time" Ocean Surface Wind Retrievals form Satellite"
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166 "User Manual and System Documentation of WAVEWATCH-III Version 1.18"
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167 "WAVEWATCH-III Version 1.18: Generating GRIB Files"
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168 "WAVEWATCH-III Version 1.18: Post-processing Using NCAR Graphics"
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169 "Impact on NCEP Numerical Weather Forecasts of Omitting Marine Ship and Fixed Buoy Reports"
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March 29	“Assimilation of GPS Limb Sounding Data into the Global Data Assimilation System”	(Matsumura)
May 13	“Clear-Air Adjoint-Method Wind Retrievals from the WSR-88D Network”	(Porter [NSSL])
May 17	“Optimal Program Reversal Schedules”	(Griewank [TU Dresden and INRIA Sophia-Antipolis])
May 20	“The Oklahoma Mesonetwork: Eight Years Later”	(Crawford, Richardson, Basara [University of Oklahoma])
June 21	“Prospects for Passive Microwave Data Assimilation Over Clouds and Convection”	(Gasiewski [ETL])
September 20	“Diurnal Variation of Precipitation Over the South-East Asia: Two-dimensional Numerical Simulation”	(Satomura [Kyoto University])
October 4	“Experiences With Data Assimilation of WSR-88D Radar Data at the Sterling, Virginia Weather Forecast Office”	(Crook [NCAR])
November 30	“Global Optimization of Numerical Models by Simulated Annealing”	(Campbell [University of Maryland])